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THE ARCHAEOLOGICAL POTENTIAL OF INFORMAL LITHIC TECHNOLOGIES: A CASE STUDY OF ASSEMBLAGE VARIABILITY IN WESTERN NEW SOUTH WALES, AUSTRALIA

By

Matthew J. Douglass

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Anthropology, The University of Auckland, 2010
Abstract

This thesis addresses the research potential of informal lithic technologies through a case study of surface deposits from western New South Wales (NSW), Australia. The defining characteristic of the lithic remains of the region is a dearth of formalized patterning. As a consequence, researchers have historically equated these remains with a casual approach to lithic technology where it is often assumed that artefacts were produced on an as needed basis.

This apparent simplicity is in marked contrast to the demanding environment of the region. Water and food resources are extremely limited and historic observations indicate that Aboriginal populations coped with these conditions by employing strategies of land use based on short-term occupations and high mobility. It is therefore an anomaly that populations living under such conditions would be so unconcerned with the organization of their technology.

An exploration of this anomaly guides the research presented in this thesis. Was the organization of Aboriginal lithic technology truly simple or instead is the perception of simplicity an artefact of previous interpretation? The goals of this thesis go beyond questioning the perception of simplicity to the larger question of how informal technologies can be used to understand past behavioural organization.

To investigate these questions, this thesis makes use of an abundance of assemblage data gathered by the Western NSW Archaeological Programme. The results of this research indicate that while the vast surface record of the region may present what appears to be a largely undifferentiated record, contextualization shows that Aboriginal occupation of the region was anything but uniform. Chronologies developed through extensive radiocarbon dating demonstrate that periods of increased
Aridity are correlated with decreased evidence of Aboriginal occupation, thus suggesting territorial reorganization in the face of environmental deterioration.

The study of lithic technological organization and the curation concept provide a theoretical perspective with which to explore the possibility for similar dynamism in the largely informal lithic technologies of the study region. While current studies of stone artefact curation are largely based on retouched tools, the curation process may exist in the absence of retouch. A methodology based on the quantification of cortical surface area is presented as one means through which curation without retouch may be explored. This methodology is based on the principles of solid geometry and enables comparison between the quantities of cortex observed in lithic assemblages and that which should be present given the size and shape of the stone nodules from which artefacts were produced. Deviations between observed and expected values indicate the effects of artefact transport on assemblage formation.

Application of the cortex methodology indicates that cortex is extensively underrepresented in the NSW assemblages, meaning artefacts were transported away from their place of production. This result is in marked contrast to the perception of Aboriginal technological expedience. Further investigation of the cortex methodology, the development of refined techniques and the completion of additional fieldwork enabled a more in-depth test of the initial result. Viewed from a variety of perspectives, further study supports the initial interpretation.

Utilizing spatial patterning in assemblage cortex proportions, the data for this study are then used to investigate the scale of Aboriginal mobility. Interpretation of this patterning provides insights into the organization of land use at a landscape scale and thus demonstrates a greater appreciation of the potential for informal lithic technologies to inform on the organization of the past.
Acknowledgements

Many People have helped in the completion of this thesis and I would like to thank all of them for their support. Some deserve special mention. First and foremost, I would like to thank Simon Holdaway for inviting me to join the Western New South Wales Archaeological Programme and for being a constant source of support and inspiration to this research. I must also acknowledge the great help he and his family have been to my family during our stay in New Zealand. Trish Fanning has been a source of help and encouragement and was instrumental to the completion of my fieldwork. Thanks to LuAnn Wandsnider both for fostering my interest in surface archaeology and for her continued support throughout the years.

Harry Allen and Peter Sheppard have generously read and commented upon multiple drafts related to my thesis research. This work has also benefitted greatly from discussions with Jack Harris, Harold Dibble and Peter Bleed.

Thanks in General to the Western New South Wales Archaeological Programme and to Simon, Trish and Justin Shiner for granting access to the WNSWAP database.

Thanks to the Wilcannia Aboriginal community for their support. I would particularly like to recognize Walrpa Thompson, Murray Butcher, Robert, Peter and Travis Hunter, Badger Bates and Gerald Quayle for their warm hospitality while in Barkindji country.

Thanks to the staff at the Fowlers Gap Arid Zone Research Station, rangers at Paroo-Darling National Park and to the Harvy and Harrison families at Pine Point and Langwell stations for allowing me to revisit the WNSWAP study locations, and for their assistance while in the field.
Many of the students and staff of the department of Anthropology at the University of Auckland provided assistance including, Bruce Floyd, Sam Lin, Daniel Parker, Shezani Nasoordeen, Thom Barker and Tim Mackrell.

A University of Auckland International Doctoral Scholarship funded the majority of this research. University of Auckland Research Fund and Faculty of Arts Research Fund Grants provided additional funding for field work.

Finally, I would like to thank my family for their continued support. Special thanks are owed to my wife Christie and young son Parker for making my research at Fowlers Gap a family affair. Those two weeks were the finest I have yet to spend in the field.
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1.1 Introduction

Flaked stone artefacts represent one of the most abundant artefact classes. Because of their durability, they comprise the bulk of the archaeological record that remains to study in many contexts. As such, stone artefacts are one of the most important data sources for understanding prehistoric human behaviour. Lithic studies have produced a great deal of information on tool morphologies and modes of core reduction, but of greater value is the potential stone artefact assemblage analysis has to inform on behavioural organization in the past.

Lithic analysts over the last several decades have moved away from description to establish links between prehistoric technological strategies and the circumstances under which these strategies were performed. These efforts are subsumed under the rubric of ‘lithic technological organization’ (e.g. Torrence 2001; Nelson 1991) and represent a significant development in the archaeological understanding of past behaviour. Topics include artefact design, production, maintenance and discard and how these processes relate to environmental variability, raw material availability, mobility and subsistence. (e.g. Andrefsky 1994a, 1994b; Binford 1973, 1977, 1979; Bleed 1986; Kelly 1988; Nelson 1991; Parry and Kelly 1987; Shott 1986; Torrence 1983, 2001).

While the impact of lithic studies has increased, current approaches to lithic technological organization and the methodologies upon which they depend are predominantly focused on retouched tools and formalized core morphologies. This presents a challenge for researchers working in contexts dominated by unretouched
flakes and informal cores. Using current methodologies, the majority of materials in these assemblages have only a limited impact on behavioural interpretation.

This thesis therefore addresses the behavioural significance and information potential of informal lithic assemblages through a case study investigating an anomalous situation presented by the apparent simplicity of the lithic technology of western New South Wales, Australia and the demanding environmental conditions under which this technology developed. The case study is limited to a portion of the Australian arid zone, however the implications of its findings have relevance for the investigation of lithic technological organization that extends well beyond the Australian continent.

The data for this study result from 13 years of research by the Western New South Wales Archaeological Programme (WNSWAP) on the expansive surface artefact scatters found throughout the region. The stone artefacts within these scatters are characterized as a flake and core technology (Flenniken and White 1985) and display limited morphological standardization. Retouch constitutes less than five percent of assemblage contents and cores show little evidence of platform preparation or formalized reduction. Australian archaeologists have commented that assemblages like these reflect a casual or opportunistic approach to flaked stone technology. This impression is linked to a perceived lack of time and energy investment where artefacts are manufactured expediently in order to satisfy immediate needs.

Access to water and subsistence resources is extremely limited in arid parts of Australia and is further subject to considerable variability with the unpredictable and localized nature of rainfall. Historic observations indicate that Aboriginal populations
responded to these conditions with a strategy of land use based on high individual and
group mobility (e.g., Keen 2004 and references therein). Why should the assemblages
from such a variable environment be dominated by flakes and cores, and show limited
retouch? Why instead don’t these remains display the characteristics of increased
levels of investment in artefacts expected under such conditions (e.g., Nelson 1991;
Parry and Kelly1987)? Addressing this anomaly goes beyond questioning the amount
of investment in lithic technology and how this relates to archaeological concepts
such as curation and expedience. Whether assemblages readily display formalized
patterning or not, the use of lithic technology reflects the organizational structure of
past behavioural systems. While the preservation of lithics provides the means for
moving from a static archaeological record to a dynamic understanding of the past,
without a greater appreciation of the information potential offered by unretouched
flakes and informal cores, this value will remain largely unrealized especially in
regions like western NSW.

1.2 Thesis Organization

In this thesis I present strategies for studying the organization of informal lithic
technologies and their use for studying past systems of land use. The chapters are
broken into two parts.

Part One reviews the anomaly between technology and environmental predictability,
the formational nature of the archaeological record, its effects on behavioural
interpretation, and the data for this study. This information is a compendium of the
research efforts of WNSWAP over the past 13 years and serves as a backdrop of the
knowledge base that was an impetus for the subject matter of this thesis.
Chapter Two provides a more in-depth overview of the physiographic, environmental and archaeological record of the western NSW study region. It describes the anomaly that exists between the technology of the region, perceptions of its significance and the environmental context under which it was developed.

Chapter Three discusses the processes operating to structure the abundant surface record in the study region. Before behavioural interpretation can proceed, archaeologists must first understand the formational nature of the record and the implications this structure has for linking material traces back to behavioural interpretation. This chapter presents an overview of the interrelationship between artefact accumulation and post-depositional modification along with an overview of the complex geomorphological environment specific to the study region of western NSW.

Chapter Four presents the theoretical and methodological developments needed to contextualize the complex formational histories of surface deposits and presents an overview of study assemblages comprising over 123,000 artefacts.

Chapter Five serves as a bridge between the wealth of contextual information that has guided this study and the theoretical and methodological perspectives for studying informal lithic assemblages. The chapter starts with an overview of time-averaged assemblages and the theoretical perspectives that are necessary for their study. A consideration of the WNSWAP data and their relevance for understanding Aboriginal occupation within western NSW throughout the mid to late Holocene then concludes the review. An overview of the study of lithic technological organization, the concepts
of curation and technological expedience, and the challenges current practices within lithic analysis present to researchers working with informal assemblages then sets the stage for the research perspective developed in this study.

Part Two presents the development of methodologies for analysing informal lithic assemblages and their application to the WNSWAP study assemblages. It concludes with a consideration of the implications of this study for understanding Aboriginal adaptation within the study region.

Chapter Six presents a methodology for exploring artefact transport based on the quantification of cortical surface area (Dibble et al. 2005). This methodology is experimentally tested to investigate its applicability with Australian artefact recording protocols and is then applied to the WNSWAP assemblage data. Results suggest that cortical surface area is underrepresented within each of the study assemblages, meaning substantial quantities of overly cortical artefacts were transported away from the location of their manufacture. The general perception of the casual nature of Australian lithic technology is considered in light of this observation.

Chapter Seven discusses additional studies used to refine the interpretation of cortex patterning. The first section of this chapter addresses the quality of the data upon which the cortex methodology was applied and its reliability for accurately interpreting archaeological cortex proportions using laser scanning and computer simulation. The second section presents additional methodologies to refine the measurement of variables critical to the cortex methodology. Alternative means for testing the observation that substantial quantities of overly cortical artefacts were
removed from their place of production are developed. These methodologies are based on linear regression analysis with experimental assemblages and the use of survey techniques to more precisely investigate variability in stone raw material within the general study region.

Chapter Eight outlines field work in three study areas, Paroo-Darling National Park, Pine Point and Langwell Stations, and Fowlers Gap Arid Zone Research Station where the methods outlined in Chapter Seven were employed. The field protocols used in this additional study along with the data acquired through their application are presented.

Chapter Nine provides a more in-depth perspective on the initial study of cortex patterning amongst the WNSWAP assemblages. Results of the refined analysis replicate the initial observations presented in Chapter Six. These results provide conclusive evidence that Aboriginal populations relied on the substantial use of artefact transport as part of a technological strategy based on high mobility.

Chapter Ten concludes with a discussion of the behavioural implications of the observations gained through the measurement of cortex. The relevance of these observations about the use of informal lithic technologies and their relationship to the environment of western NSW is evaluated to investigate the nature of Aboriginal technological organization during the mid to late Holocene. Discussion then considers how these technological strategies and the patterning in archaeological cortex proportions inform on the strategies of land use that were a necessary part of the
Aboriginal adaptation to the demanding conditions of living in an sparse and unpredictable environment.
Chapter Two

Archaeology and Environment of Western New South Wales
2.1 Introduction

The data for this study consist of surface archaeological assemblages distributed throughout far western New South Wales (NSW), Australia. Western NSW is a region characterized by contrasts, most notably the unpredictability with which the environment oscillates between the extremes of severe drought and flooding rains (Holdaway et al. 2009). The resource base is marginal and surface water is largely constrained to ephemeral water features dotted across an otherwise vast, sparse and arid land (Figure 2.1). Chapter One introduced the anomalous situation between the apparent simplicity of Aboriginal lithic technology and the demanding environment that typifies the region. This chapter will expand on this theme through a more detailed presentation of the characteristics of the environment, lithic technology and structure of raw material availability within western NSW.
Figure 2.1: Landscape View Onto the Vast, Sparse and Arid Landscape of Western NSW, Australia.
2.2 Overview of the Study Region

Western NSW falls within the southeast margin of what is known as the Australian arid zone defined as areas with “an excess of potential evaporation over precipitation” (Mabbut 1971:66) which account for approximately 70 % of the total land mass of the Australian continent. Western NSW itself extends from the town of Cobar in the east to the South Australian border to the west and from the Murray River in the south to the Queensland border in the north (Shiner 2008).

There is considerable environmental variation within this expansive area. Riverine flats and clay plains are found along major water courses (e.g. the Murray and Darling Rivers). Sand dunes are found in various locations most notably in those areas surrounding the margins of lakes (e.g. Willandra lakes) and in the Corner Country in the far northwest. Upland and pedimont range systems occur along the foothills and high plains of the Barrier Range and stony desert and mesas with low relief are common in the far north. Ephemeral lakes occur along the Murray Darling River systems and isolated lakes and bog swamps within small internal drainage systems can be found dispersed across much of the region (Shiner 2008: 37). Combined these zones provide a diverse physiographic backdrop with which to explore prehistoric use of the arid zone.

2.3 The Archaeological Record of Western New South Wales

The Australian arid zone offers a unique context with which to explore landscape scale patterning of the surface archaeological record (Holdaway et al. 2000).
Vegetation cover is naturally discontinuous within the region thus affording high artefact visibility. Accelerated erosion over the last 150 years has further contributed to the abundance of surface archaeology in the region (Fanning 1999). Through the removal of large quantities of sediment from the lower slopes and valley floors of alluvial drainage systems, an abundance of surface archaeological material now lies scattered across the previously buried valley floor margins. There is considerable variability in artefact densities within these zones. While some areas present diffuse scatters, it is common to observe concentrations in the thousands to tens of thousands distributed across a single surface exposure. Artefactual abundance is markedly lower upon the less geomorphologically active (i.e. more ancient) surfaces in the uplands though material does occur in dense concentrations adjacent to outcroppings of knappable stone.

The conditions of Australia’s arid interior are not conducive to good archaeological preservation. As a result wood, bone and other organic materials are largely absent. The dominant artefacts found upon these exposed surfaces are scatters of flakes and cores distributed between the deflated remains of heat-retainer hearths (Figure 2.2) (Holdaway et al. 2002, 2005, 2009). A smaller component of seed grinding implements can be found within many of these exposures, but these account for only a very small proportion of overall assemblage contents. What little ground stone that does exists is often broken (some pieces having been reused as heat retainers in hearths) though the largely fragmentary nature of this artefact class may to some extent reflect the removal of complete forms by collectors (Griffiths 1996). There are also mounds near the rivers (e.g. Littleton 2007) as well as a multitude of rock art sites.
The composition of lithic assemblages varies both spatially (Shiner 2006, Shiner et al. 2007) and as a reflection of overall exposure age and therefore overall time depth of assemblage formation (Holdaway et al. 2008c). Variability in raw material access has a noticeable effect on artefact density, but it is not on its own the sole determinant of assemblage composition. A generalized distance-to-source decay relationship is detectable even over short distances of a kilometre or less in western NSW (Doleman et al. 2001; Holdaway et al. 2004).
Figure 2.2: Heat-retainer hearths. A pit is dug, a fire is set inside and stones added. Food is then placed in the pit. Left and Centre (modern hearth), meat is placed on gum leaves resting over coals. Leaves (and feathers) are then placed on top and coals are added. Murray Butcher then seals the hearth with corrugated tin and sediment. Right, Murray and Simon Holdaway excavate the remains of a deflated hearth for radiocarbon dating.
Figure 2.3: Typical Western NSW Examples of Tool Forms that Mark the Emergence of the Australian Small Tool Tradition. Left, unifacially retouched pirri point; Centre, backed geometric microliths; Right, tula adzes (a hafted flake that is resharpened on the distal end, often until it has almost reached the platform giving the appearance of a slug).
Figure 2.4: Lithic Scatter. While retouched forms are present in western NSW assemblages, the vast majority of the record reflects unretouched flakes and unprepared cores
2.3.1 Australian Flaked Stone Artefacts

In general Australian flaked stone artefact assemblages have been separated into two temporal groupings, the Australian core tool and scraper tradition and the Australian small tool tradition. The Australian core tool and scraper tradition (Bowler et al. 1970), which relates to assemblages dating from the Pleistocene colonization of Australia until approximately 6000 BP, is characterized by core tools (e.g. horse hoof cores), steep edged scrapers and flat scrapers (see Holdaway and Stern 2004 for a description). The Australian small tool tradition (Gould 1969) marks the addition of new tool forms including backed blades, the tula and burren adze and bifacial and unifacial points (Figure 2.3) in the mid to late Holocene (see Holdaway and Stern 2004 for description). Once established, these new forms remained part of the greater suite of Aboriginal lithic technologies up until the abandonment of flaked stone tool use following European contact. While these two groupings are presented as two discrete packages, they are not homogenous. There is considerable spatial and temporal variation and artefact types from each appear and disappear through time (Hallam 1985; Hiscock and Allen 2000; Hiscock and Attenbrow 1998; Jones 1985; Cosgrove 1995).

While various distinct tool types are present, the most striking characteristic of the lithic technology of Australia’s arid zone is the scarcity of formal patterning (Figure 2.4). Instead, Australian lithic technology is characterized as a flake and core industry (e.g., Flenniken and White 1985) and retouched tools are often rare, comprising less than five percent of total assemblage contents for the assemblages addressed in this study (e.g.
Holdaway et al. 2004; Shiner 2006; Shiner et al. 2005). Within western NSW, the majority of retouched forms that are available for study represent utilized flakes, notches and some marginally retouched scrapers. Backed blades, adzes, and point forms remain quite rare (see Appendix Two and Holdaway and Stern 2004 for definitions of Australian tool types).

Investigations into core reduction show a similar lack of distinctive patterning. While some Australian studies have documented the presence of highly patterned reduction sequences (e.g. tula cores Moore 2004, Witter 1992), the majority of core forms within the region are the unifacial and multidirectional varieties typically referred to as amorphous or expedient cores (e.g. Parry and Kelly 1987; Prasciunas 2007; Wallace and Shea 2006), as opposed to the more formalized and prepared varieties emphasized by researchers studying reduction strategies and sequences. In fact, Flenniken and White (1985) have argued that the entire range of stone tool variability within Australia can be accounted for by a single reduction sequence.

The dearth of formalized patterning in Australian stone tool and core morphologies has caused much consternation. Australian artefact morphologies are not well suited to the development of spatially and temporally meaningful typologies. Even the suite of tools types that mark the advent of the Australian small tool tradition is no longer accepted as forming a distinct temporal horizon (Hiscock and Attenbrow 1998, Hiscock 2002). There are arguments for regional variation (see Holdaway and Stern 2004 Chapter Seven), but
Australian examples posses nowhere near the spatial and temporal resolution noted in other parts of the world (e.g. North American bifaces).

Though ethnographic observations indicate substantial mobility among Aboriginal people – a circumstance often associated with an increased emphasis on formal core reduction and standardized artefact morphology (e.g. Parry and Kelly; Wallace and Shea 2006) – researchers have remarked on the expedience or opportunistic nature of Australian lithic technology (e.g. Horne and Aiston 1924; Gould 1968; Gould et al. 1971; Hayden 1977, 1979; Kelly 1988, Parry and Kelly 1987; Tindale 1965). This simplicity in form has often been equated with a lack of technological sophistication, or a decreased level of concern or investment in the production and use of flaked stone artefacts.

J. Peter White (1971) summarized this perspective by relating a number of views on the status of lithic technology in Australia (e.g. Chard 1975:161; Gifford and Shutler 1956:66-7; Van Heekeren 1972). His cataloguing of the low regard researchers had for the patterning in Australian lithic assemblages included quotes such as that offered by Grahame Clark (1968:21-2):

The crude and rather colourless nature of the industry may serve to remind us that the original Australian Aborigines issued from one of the most unenterprising parts of the late Pleistocene world.
Other Accounts have suggested a similar equivalency between informal artefact morphology and the nature and attitude of those who produced the technology. Horne and Aiston (1924:91-2) provide one such account:

In describing these tools it must always be remembered that the casual nature of the black does not allow him to keep any tool for the one purpose. He is just as likely to use his best stone knife to scrape a weapon as he is to use any flake he may pick up…This casualness is what makes it so hard to say specifically that a tool is used for any one purpose…

Though contemporary scholars are decidedly less demeaning in their descriptions, similar observations of opportunism and casualness remain a feature in some accounts of Aboriginal technology. Hayden (1977:179) provides a clear example of how his expectations of careful and deliberate stone tool craftsmanship were quickly dispelled when confronted with Aboriginal tool use:

There are a number of factors which led to this feeling of ‘is that what I came all this way to see?’ Probably the most immediately influential was the attitude of the Aboriginals themselves. They seemed uninterested in the stone they were using to the point of ignoring it except when the stone no longer was suited for continued use; they were predominantly interested in the work they were doing with the stone, such as making spears…This lack of interest in stone was my first surprise…Another...[was that] there were no master craftsmen of stone tool
making…No one was capable of controlling the stone medium to anywhere near the
degree attained by the renowned knappers in the Occident…Instead, there was only
a moderate degree of control over the stone medium; suitable flakes for work were
often picked out of almost random flakes. However, the flakes that were obtained
were perfectly adequate to the technological needs of all task activities.

A major reason Australian lithic technology is characterized as casual relates to the lack
of a relationship between artefact shape and function for the majority of artefact forms.
Ethnoarchaeological study of tool using behaviour documented how a wide variety of
different flake and core morphologies were deemed suitable for many different tasks by
their Aboriginal users (e.g. O’Connell 1977; Hayden 1977; White 1971) including the use
of unmodified natural pieces in some instances (e.g. Mountford 1941). These findings
were corroborated by similar investigations into tool use as inferred through use-wear
analysis of ethnographic and archaeological specimens (e.g. Fullager 1986, 1988;
Fullager and Jones 2004; Kamminga 1978, 1982).

Similarly, ethnographic descriptions of core reduction have often commented on the
indifference with which Aboriginal knappers approached flake production (e.g. Gould et
al. 1971; Hayden 1979; Hiscock 2004). Tindale (1965:140) provides a detailed example
of a “casual” core reduction when describing quarrying activities of Pitjandjara and
Nakako men at an outcropping referred to as Pulanj-pulanj. He notes how boulders were
first shattered and the:
Smaller pieces were then struck, virtually at random, either with the abovementioned hammer stone, which was passed from hand to hand as required, or with a piece of the mother rock. When a suitable-sized flake was detached by the hit and miss process, it was set to one side. When a boulder of particularly good stone was discovered it was alternatively hurled down and struck at with the hammer until no further flakes could be obtained from the core which remained.

Hayden’s (e.g. 1979: 26, 55-6, 92, 121-22) observations of flake production show a similar lack of standardized production with flakes removed from unmodified cobbles or chunks of stone without preparation. Often only a few flakes were produced and then tested for use in completing a task. On other occasions a pile of flakes was amassed through the nearly complete reduction of a core.

In summary, the distinctiveness of Australian arid zone lithic technology is its morphological simplicity. Blades and some cores that suggest formal reduction technologies are found, but in limited quantities. Instead, the majority of artefacts are non-distinct flakes and cores that were worked with little standardization or preparation.

Retouch of flaked stone artefacts is relatively rare, averaging less than five percent of all artefacts within western NSW assemblages. The majority of tool forms consist of utilized flakes (flakes with modified edges forming angles less than 60 degrees), scrapers (one or two margins of continuous retouch) and notched flakes (either single or multiple notches). The meagre quantities of specialized tool forms are restricted to the tula adze,
geometric microliths and pirri points (a unifacially flaked point). Retouch of tools is generally light, with intensive retouch only consistently evident on tula adzes (Holdaway and Stern 2004).

This scarcity of standardization has led to the widely held position that Australian lithic assemblages reflect a casual or opportunistic approach to flaked stone technology. This impression is linked to a perceived lack of investment in the stone artefacts that were used for a variety of daily tasks and the overriding assumption that flake production was largely oriented toward the attainment of immediate needs – the majority of tools presumably being discarded after the completion of a task. In essence, the patterns observed in Australian lithic assemblages are presumed to reflect expedience rather than the greater investment that has come to be associated with artefact curation.

2.4 Environmental Overview

This perception of simplicity and casualness in the lithic technology of the arid zone contrasts with the demanding environmental conditions that are found there. The distribution of resources within the Australian arid zone is patchy, of low density and subject to large fluctuations in relative abundance, and relative to other deserts in the world displays a lower diversity of flora and fauna species (Gould 1991; Stafford Smith and Morton 1990). The distribution of trees is largely confined to larger watercourses, and vegetation cover in the remaining landscape is limited to sparse distributions of chenopod shrubland. Terrestrial animals (e.g. kangaroo and emu) travel in small spatially
dispersed groups or as individuals. Smaller marsupials and reptiles live in burrows (e.g. echidna and various species of lizard) and the edible vegetal resources that are available are calorically poor and ill suited for bulk storage (Holdaway et al. 2009). All of these factors make the Australian arid zone a depauperate resource base for humans (Gould 1991). Of even greater concern, however, is the limited availability of water. Australia is the driest continent and there are few sources of permanent water in the region of western NSW. Instead water pools in dry creek beds, rock holes and other features that hold water following rain. During much of the time these features remain dry.
Figure 2.5: Short-term Environmental Variability. View overlooking same valley (Rutherfords Creek) in the absence of rain and shortly after a punctuated rainfall.
Figure 2.6: Ephemeral Water Features. Features such as that pictured above remain dry at most times, but collect water following rain. When containing water, they served as important attractors for Aboriginal occupation. Stone artefact and hearth densities are often concentrated in areas surrounding these features.
Western NSW has an average annual rainfall of less than 250mm and pan evaporation commonly exceeding 2,000mm; these averages are further subject to major fluctuations largely connected to El Niño southern oscillation and La Niña episodes which bring alternating periods of severe drought and higher than average rainfall. There are few paleoclimatic indicators with which to interpret past variation in these cycles, but most evidence suggests a climatic optimum occurring around 4000 BP followed by desiccation and aridity from about 3000 BP to about 1500 BP and amelioration up to the present (Holdaway et al. 2002). Aside from these averages, however, the region is subject to marked local climatic variability. It is this unpredictability that is in many respects the defining characteristic of the arid zone.

Rainfall is infrequent and unpredictable, the majority coming in punctuated and highly localized events (e.g. Dunkerly 1996). A clear demonstration of this is found in observations made on a single rainfall event that occurred within the confines of the Fowlers Gap Arid Research Station (Fanning et al. 2007). Using rain gauge data collected over a 24 hour cycle during which a low pressure system passed through a large area of western NSW in February 2000, differences in rainfall ranged between 15 to 155.8 mm within areas separated by no more than a few kilometres. Some locations associated with runoff from high rainfall saw flooding that resulted in considerable modification to the surrounding landscape, while areas receiving limited rainfall saw only a slight increase in vegetation cover the following season. These observations illustrate the extremely fine scale by which rainfall varies within the region. A consequence is that areas receiving rain experience brief increases in water availability and relative though
limited increases in land productivity while surrounding areas remain dry. These factors serve to exacerbate the noted patchiness of resource and water availability in the arid zone.

Ethnographic observation suggests that Aboriginal populations followed a strategy where small, highly mobile groups ranged over large expanses of territory to meet their subsistence needs (e.g. Cane 1984; Gould 1991; Keen 2004 and references therein). Population densities were low and residence groups seldom remained stable, but were instead fluid in composition and size as people coalesced and fragmented. The unpredictability with which the environment changed precluded the emergence of seasonal patterns of occupation and mobility and the location and conditions of future occupations could not be planned well in advance.

Because the productivity of individual parcels of land varied greatly in both the long and short-term, Aboriginal populations did not have strict rights concerning access and use of their territories and the resources within them. Though there were systems in place for establishing land ownership, population densities and high mobility meant that territories were largely undefended, and rights to ownership differed markedly from rights of land use (Peterson and Long 1986; Keen 2004).

In a comparative study of ethnographic populations distributed across much of Australia, Keen (2004) found a broad similarity concerning rights to land use where individuals
within all populations had rights of access to the land and resources of multiple landholding groups. This was especially apparent in the arid zone.

In the western desert, a multitude of factors could be used to assert land rights. These included: place of birth, place of conception, place of initiation, standing family association with the land, ancestral journeys connecting a given location to an individual’s own country, time spent in country, and finally the possession of general knowledge of the country (e.g. Keen 2004; Cane 1984; Peterson 1983; Peterson and Long 1986). Similar observations from populations along the Darling River demonstrate territorial permeability and an array of social mechanisms to ensure people had rights to the resources distributed over vast areas (Allen 1972, 1974; Keen 2004; Mathews 1906; Parker 1905). The versatility by which rights to land use could be negotiated was undoubtedly of critical importance for buffering against the unpredictable conditions of the arid zone.

As the above description has indicated, the Australian arid zone presents a number of challenges to human use and occupation. So it is a strange anomaly that people living in what is a sparse, unpredictable environment that necessitates frequent movement would be so unconcerned with the stone artefacts they produced and used. Why develop a lithic technology based on informal flakes and cores and limited retouch? Why instead didn’t they possess a technology that would typically indicate the increased levels of investment that might be expected under such conditions?
2.5 Lithic Raw Material Availability

The fall back argument has always been that the apparent simplicity of Australian lithic technology was a consequence of the raw material rich environment of the arid zone. Researchers have often remarked how the availability of abundant raw material decreased the need for investment in the organization of lithic technology thus resulting in an emphasis on what is generally referred to as expedient or informal technologies (e.g. Andrefsky 1994a, 1994b; Gould et al. 1971; Kelly 1988; Nash 1996; Odell 1996; Parry and Kelly 1987; Spencer and Gillen 1927:25-26; White and O'Connell 1982:162-163).

One of the clearest descriptions of this perspective, and one that make use of Australian examples, is that offered by Kelly (1988: 719) who states:

…[T]he type and distribution of local raw material is the primary factor affecting the lithic technology of foragers. When raw material is abundant and of adequate sharpness there is no temporal or spatial difference in the location of raw material and the location of stone tool use; in effect, stone tools have no role to play, and we can expect groups living under such circumstances to employ an expedient flake technology…For example,…among the Alyawara of central Australia many morphological tool types were determined by the locally available material, either chert stream cobbles or outcrops of quartzite; this also is true of several other highly residentially mobile Australian and Tasmanian hunter-gatherers.
The region of western NSW is indeed rich in knappable lithic raw material, silcrete and quartz being the dominant lithologies used for artefact production. In some areas silcrete dominants while in others it is quartz that predominates.

Silcrete occurs in outcroppings of duricrust and associated boulder mantels that form the residual capping of mesas and plateaus (Langford-Smith 1978) and also as cobbles and gibbers that can be found along hillslopes, desert pavements and in the channel beds of the many dry creeks found throughout the region. Quartz is occasionally found in outcroppings but is most often found as cobbles and gibbers. A smooth, rounded cortex covers the exterior of both silcrete and quartz nodules (Figure 2.7).
Figure 2.7: Western NSW Raw Material Sources. Cobble Lined Creek Beds (Top), Boulder Mantled Outcropping (Middle) and Gibber (Large Gravel) Pavements (Bottom).
The flaking quality of silcrete varies depending on the presence of inclusions within the stone matrix. The finest quality silcrete is nearly pure silica with a flaking quality approaching the best flint, while the poorest silcretes have large inclusions and other flaws that greatly reduce flaking quality. In general, however, silcretes throughout the region are of medium to high quality (Holdaway et al. 2004, 2008c).

Quartz varies in flaking quality. Lower quality quartz is prone to flaws and cleavage planes that inhibit the predictability with which it can be fractured. Other grades have moderate to high flaking qualities that allow knappers to produce artefacts with a high degree of control where the characteristic landmarks of conchoidal fracture are clearly visible. The knapping quality of quartz is, however, generally inferior to that of silcrete and there is increased evidence of bipolar technology in assemblages in which it is the predominate material (Holdaway et al. 2008c).

In summary, western NSW presents an abundance of raw material sources suitable for the production of stone artefacts. The argument for Australian expediency therefore has often been that the rich lithic landscape afforded cheap and easy production and that the need for a cutting edge could be sufficed more or less immediately – the result then being a casual approach to the organization of lithic technology. The problem with this argument, however, is that while it is true that stone is in abundance in the region, it is not ubiquitous; people could not have relied on always having stone immediately on hand where and importantly when they needed it. Because people were frequently on the move, it would have been difficult to anticipate the availability of raw materials for future
needs. This is particularly true for larger fine grained materials that would enable versatility in the flakes produced; gibbers are small as are the flakes and core tools that were produced from them. Simply put, even though material is in relative abundance in the region, if Aboriginal populations were truly reliant on technological expedience, then in many situations, as they moved across the greater landscape, a lack of immediacy to stone access would mean that they were frequently forced to go without. In the context of a sparse and unpredictable resource based, being caught short-handed likely carried a considerable cost.

2.6 Conclusion

The overview of the physiography, environment and archaeological record of western NSW presented in this chapter has outlined many of the unique conditions of the Australian arid zone. These features serve to highlight some of the many challenges the arid zone presents to human occupation. As described here and in Chapter One, the complexity of the environment is in stark contrast to the apparent simplicity of the lithic remains that are found in such abundance in the surface archaeological record of the region. The abundance and spatial extent with which these surface remains can be studied does, however, present a bountiful data source with which to explore this anomaly. Before interpretation of assemblage patterning in these contexts can proceed, however, the nature of archaeological record formation must first be considered. This will be presented in the Chapter that follows.
Chapter Three

Formation of the Archaeological Record
3.1 Introduction

The preceding chapter provided a broad outline of the characteristics of the environment and archaeological record of western NSW Australia. One very important feature is the abundance of surface archaeological deposits that occur across much of arid Australia and the tremendous opportunity this offers for exploring prehistoric behaviour at a landscape scale. These deposits do, however, present a number of contextual challenges that complicate behavioural interpretation.

Archaeological patterning at a landscape scale can be deceptive in that it appears to reflect single activities or site types suitable for the reconstruction of prehistoric settlement patterns (e.g. Cane 1984; Thorley 1998; Veth 1993). A consequence of such reconstruction is an assumption of broad contemporaneity between deposits which creates false perceptions of long-term stability in patterns of settlement and land use. The fact that Australian stone artefacts are not well suited to seriation further creates the impression of an unchanging and timeless past. These interpretations fail to take into consideration the complex geomorphological and behavioural histories represented by individual surface exposures (Holdaway and Fanning 2008; Holdaway and Wandsnider, 2006; Holdaway et al. 2008a, 2008b; Shiner 2006; Wandsnider 2003).

Because of their variable geomorphological histories, surface exposures of archaeological material positioned across the landscape do not reflect a uniform history, but instead present a patchwork of archaeological accumulations of different age and temporal grain.
As formational phenomena, individual archaeological deposits each have their own unique structure. Without proper contextualization, researchers run the risk of mismatching the scale of interpretation to the scale of record formation. This chapter presents a brief overview of the primary factors influencing the formation of the archaeological record, both in general and specific to western NSW. The chapter that follows will then outline a methodology capable of dating the occupational histories represented in the vast deflated surface record of the Australian arid zone.

3.2 A Brief Overview of Archaeological Formation

The cultural component of the archaeological record owes its formation to the continued exposure of the landscape surface to the accumulation of the material residues of past human behaviour. Human activity occurs across the landscape and the archaeological record accumulates as material falls from active use within that system (Wandsnider 1996). The patterning that emerges is not a direct reflection of the total suite of behaviours that transpired (Binford 1978a, 1978b, 1982; Schiffer 1972, 1976, 1987), but instead represents the fall-out of cultural material once in systemic context. That is, the archaeological record is a record of discard (Doelman 2001; Holdaway et al. 2004; Varien 1997; Wandsnider 1998a, 1998b).

The accumulation of cultural material is not limited to a few discrete locations, but instead forms a continuous distribution reflecting the spatial extent of past land use (Dunnell 1992; Dunnell and Dancey 1983; Foley 1981a). Those areas where human
activities were concentrated reflect patches of increased artefact density within the ephemeral scatter of material remains that persists across the greater landscape (Foley 1981b; Isaac 1981).

Importantly human spatial organization across the landscape is not fixed, but instead changes as behaviour changes with the world around it. Patterns of land use are apt to change in relation to fluctuations in environmental conditions (e.g. Fanning et al. 2007), changing patterns of social organization (e.g. Mauss and Beuchat 1979), and as a result of population dynamics (e.g. Binford 1980, 2001). Portions of the landscape once associated with one set of activities may later be used for a completely different set of activities (Wandsnider 1998a, 1998b). Through time, locations once occupied infrequently may be used often while others may fall to disuse.

In this sense, human activity within the landscape is the source of material debris that then accumulates upon or near the surface of the landscape. As a result of the dynamic nature of past land use, patterning in the archaeological record does not betray the character of that use at any point in time, but instead represents a density map of the various spaces that were utilized through time (Camilli and Ebert 1992; Ebert 1992). Concentrations of archaeological material seldom represent discrete occupations; these are not sites, as in real places with distinct boundaries, but what Dunnell (1992:27) called “accretionary phenomena.” All things being equal, those areas that are subject to more activity will see more accumulation while those areas visited less frequently will accumulate less. This process continues so long as humans inhabit the landscape; with
more accumulation, the patterning that forms may become less representative of the short-term organizational patterns of the ethnographic present.

Cultural accumulation represents but half of the story of archaeological record formation. Once in archaeological context (*sensu* Schiffer 1972), cultural debris is subject to a host of post-depositional processes. These processes operate at a variety of spatial and temporal scales and serve to impose a contextual structure that affects how archaeological assemblages can be interpreted (Stein 1987, 1993, 2000).

From a general perspective, landscape surfaces are dominated at any one time by one of the following processes, deposition, erosion or stability (Stein 2000). Deposition results in the build-up of sediment thus covering areas once at the surface, while erosion is the process by which sediments are removed and a new surface is exposed. Stable portions of the landscape are those that are currently between periods of deposition and erosion.

The physical alteration of the landscape affects how cultural materials accumulate and the relationships that exist between these materials. Depending on the rate of landscape modification, the archaeological deposits that form will reflect different resolutions of temporal acuity (Ferring 1986). Some portions of the landscape are dynamic while others are relatively stable. Some are disproportionately influenced by one process while others may be equally touched by all three. As a result of these varying formational histories, the landscape can be most effectively viewed as a mosaic of different units of varying age and temporal grain (Bettis and Benn 1989; Wandsnider 1998a, 1998b). In essence, the
influence of post-depositional processes structures the record of human discard by partitioning it into unique packages of varying spatial and temporal extent.

From this discussion it is clear that the archaeological record is a highly variable formational phenomenon that must be contextualized in order for interpretation to proceed. While this is true of all archaeological deposits, the scale at which surface studies proceed makes the need for chronological control all the more apparent. I will now present a general overview of the dominant processes affecting the formation of the surface archaeological record in the study region of western NSW, Australia.

3.3 Geomorphic Context and Recent Landscape History of Western NSW

Geologically, Australia is characterized as an ancient land with rocks from the late Archaean to Mesoproterozoic (2,400 Ma – 1,600 Ma). The effects of geomorphological modification to these ancient features, however, has resulted in much greater complexity, where sediments deposited in the recent and immediate past frequently border surfaces that have remained exposed over the entire span of human occupation of the Australian continent (Fanning et al. 2008).

The reason for this complexity relates to episodic climactic events, particularly catastrophic flooding brought on by severe localised rainstorms (Fanning et al. 2007). As noted in Chapter Two, average rainfall is low, but variability is high, and the bulk of the rain falls during short, intense bursts. Widespread erosion as a result of flooding caused
by these episodic rainfall events removes portions of the sedimentary record and redistributes these sediments in new deposits elsewhere.

Observations of contemporary creek lines that are cut into alluvial sedimentary sequences show the presence of substantial unconformities. The record of Stud Creek in Sturt National Park in far north-western NSW (Fanning and Holdaway 2001b) has unconformities indicating gaps of several thousand years in the Holocene depositional record. While unconformities can reflect hiatuses in aggradation, the lack of evidence for the development of paleosols suggests that a more likely cause for their presence was the removal of sediments following one of these episodic flooding events (Fanning et al. 2008). Similar observations are relatively widespread (e.g. Fanning et al. 2007; Jansen and Brierley 2004; Williams et al. 1991). Valley fill chronologies from across the region (e.g. Fanning 1999; Wasson 1979; and Galloway 1986; Williams et al. 1991) show that this processes of catastrophic landscape modification extends to the late Pleistocene (Fanning et al. 2007).

The effect is a continual renewal of the landscape surface as erosion carves out existing sedimentary sequences creating new exposures, and deposition of these sediments buries surfaces already exposed. The artefacts that have previously been contained within, or have accumulated upon, the sediments removed by flood events are then incorporated into the poorly sorted deposits of ephemeral dryland stream systems and playa lake beds. Because the amount of sediment that is removed from flood events is large, the relative
densities of artefacts within these jumbles of sediment remain very low (Fanning et al. 2009b).

The sediment load carried within stream systems accumulates on previously buried surfaces, both in intermediate and terminal flood-outs and as slack-water deposits in flooded areas. The effect is a newly created surface; remains previously exposed are buried and record formation begins anew. An example of this is found at Sandy Creek within the Fowlers Gap Arid Zone Research Station. Jansen and Brierly (2004) demonstrated that the pre-European floodplain of this creek reflects the accumulation of sediment as a result of slackwater deposition following episodic erosional events that occurred between 1530 and 960 years ago (Fanning et al., 2007). Surface archaeological patterning, then reflects accumulation upon the most recent depositional surface.

The effects of these episodic, erosional events are that the archaeological record on or near the surface reflects accumulation no older than the most recent catastrophic event. Because, the rainfall that triggers these events is highly localized, different areas have different depositional histories and thus possess surfaces each of a different age.

In general, land surfaces in the geomorphologically more dynamic valley systems were formed hundreds to a few thousand years ago. Surfaces in the markedly less dynamic uplands outside of these valleys frequently predate the initial human occupation of the Australian continent. The result of this variable geomorphological history is that surfaces upon which archaeological materials rest can vary in age by millennia within the short
distance of a few hundred meters within valley systems (Fanning 2002; Holdaway et al. 2008b), and by even greater spans of time when upland surfaces are considered.

3.3.1 Recent Geomorphological History of the Study Region

The present landscape of western New South Wales is also affected by an increase in the rate of geomorphological change over the past 150 years, which has occurred as a result of the transition from the land use practices of Aboriginal hunter-gatherers to those of European pastoralists. The introduction of large numbers of herbivores (e.g. sheep, rabbits and goats), and the widespread cutting of mulga (*Acacia aneura*) for fencing and mining activities coincided with a period of prolonged drought in the 1890s. The combination of these factors reduced the vegetation cover over much of the arid zone. Once exposed, the highly dispersible sediments of the arid zone were far more susceptible to erosion by wind and water (Fanning 1994; Pickard 1994), a factor that has caused contemporary erosion rates throughout Australia to be more than 145 times greater than they were prior to European colonization (Wasson 1996). This has resulted in considerable landscape modification through increased sheetwash, rilling, gullying and wind drift (Fanning 1999).

These modifications are responsible for the widespread exposures of stone artefacts and deflated hearths within alluvial valley systems (Figure 3.1). These surface assemblages are formed as a result of the removal of the finer sediment matrix from shallowly buried deposits through water and wind erosion. Heavier sediments, including many artefacts,
are left as a lagged surface deposit. Stratigraphic relationships are lost for these assemblages, but horizontal relationships are largely maintained. Individual exposures vary in extent from a few hundred to more than 10,000 square meters.
Figure 3.1: Examples of the Abundant Deflated Surface Scatters of Flaked Stone Found Throughout Western NSW, Australia
3.4 The Surface Archaeological Record of Arid Australia

The combined effects of the highly variable geomorphological histories and increased erosion over the past 150 years present a unique opportunity for Australian archaeologists, one however that posses its own challenges. Far from destroying the archaeological potential of these deposits, the erosion-induced lagging process has greatly enhanced the scale at which archaeological patterning can be observed. Erosion has exposed areas two to three orders of magnitude larger than can commonly be approached through excavation alone, thus affording a landscape perspective onto archaeological assemblage patterning (Holdaway et al. 2000). Furthermore, because exposures of archaeological material positioned across the landscape do not reflect a uniform history, they afford the potential for investigating surface assemblage patterning from different time frames and resolutions, thus allowing a dynamic multiscalar perspective onto the organization of past human behaviour (Holdaway et al. 2008a, 2008b).

Because of the loss of vertical integrity for the artefacts once held in the sediment matrix, previous stratigraphic relationships are no longer discernable amongst these surface deposits. Instead artefacts representing many different behavioural events through time are all collapsed onto a single lagged surface, meaning the patterning observed on these surfaces is often of a considerable time depth (Holdaway et al. 2000).
This brief discussion highlights the complexity of the process of archaeological formation and the extreme contextual variability that exists across the landscape. Because of their broad temporal depth and the fact that the archaeological record is a record of discard, the material remains that accumulate for archaeologists to study do not reflect a single behavioural system nor are they a direct reflection of all activities that transpired within a given portion of the landscape. Instead, the patterning that emerges presents the aggregate signature of human discard throughout the time of record formation. Because of the complex geomorphological history of the region, different surfaces across the landscape each have their own unique formational histories.

Far from destroying the interpretive potential of the archaeological record, this formational variability affords the unique opportunity to investigate patterning at different temporal scales, thus allowing a dynamic picture of long-term human behaviour. Proceeding with this line of investigation, however, first requires a means for developing a chronology of these surface deposits. The next chapter will outline a strategy developed to contextualize the surface archaeological record of western NSW, as well as the wealth of data that have been obtained through this effort.
Chapter Four

Contextualizing the Australian Surface Archaeological Record
4.1 Introduction

The archaeological lithic assemblages used in this thesis are the product of over 13 years of research by the Western New South Wales Archaeological Programme (WNSWAP). This multidisciplinary research project is focused on providing a regional history of occupation of the semi arid portions of western New South Wales (Holdaway et al. 2005) as well as an understanding of stone artefact technology and assemblage composition of the archaeological record of the region (Holdaway et al. 2004, 2006, Shiner 2004). Central to the goals of the project is the development of a methodological approach for grappling with the unique challenges posed by deflated surface deposits that form the bulk of the archaeological record within the arid zone. This required both the development of a strategy for understanding the geoarchaeological context of record formation and developing artefact survey and analysis methods to deal efficiently with surface scatters of large numbers of stone artefacts (Fanning 1999, 2002; Holdaway et al. 2000).

This chapter provides an overview of the WNSWAP approach, including techniques developed for dating deflated surface deposits, as well as the survey methodologies used to analyse the vast quantities of flaked stone artefacts found in these contexts. Descriptions of the study areas and assemblages addressed in this thesis are also presented.
4.1.1 Developing a Chronology for Surface Archaeological Deposits

The Western NSW Archaeological Programme has developed a two-phase approach to establishing an occupation chronology for surface deposits. The age of the surface upon which artefacts are now resting is first established. Age estimates for hearths distributed across that surface are then obtained. The result is a dynamic chronological picture of human place use as it unfolded within the time perspective related in each surface exposure. A more detailed explanation of the approach now follows.

The first phase utilizes geomorphological analysis and sediment dating to investigate the history of the land surfaces on which artefacts were exposed (Fanning and Holdaway 2001b; Fanning et al. 2007, 2008). Using standard geomorphological and stratigraphic techniques, areas of archaeological exposure are partitioned so as to reflect units with the same depositional and erosional histories – effectively creating formationally relevant analytical units. The chronology of the sedimentary sequence for each unit is then determined through optically stimulated luminescence (OSL). The OSL technique measures the length of time since a sediment was last exposed to light (i.e. the time of deposition) (Aitken, 1998:6). Sediment samples are obtained by driving stainless steel tubes horizontally into the sedimentary unit being investigated. These are collected from the walls of creeks and gullies or along the sides of pits excavated into the surface of each unit. Sample estimates thus determine the age of the landsurface upon which artefacts are resting. Based on the law of superimposition, the artefacts lying on a landsurface were deposited more recently than the last time the underlying sediment was exposed to light, hence landsurface chronologies identify the
“envelope of time” (Fanning 2002) during which the occupations that resulted in the current surface record may have formed (Fanning et al. 2008).

In the second phase, the history of prehistoric occupations responsible for the accumulation of artefactual remains upon the surface of each unit is determined. The artefacts themselves cannot be individually dated, however, large numbers of deflated hearth features are often associated with these remains. As described in Chapter Two, these features are the deflated remains of earth ovens dug into the ground in which a fire was built, rocks and other heat retainers (e.g. termite mound fragments) added and food was placed for cooking. Because the sediments they were dug into have been removed by erosion, what remains is a dome of heat fractured stone and underlying sediments reflecting the former structure of the now collapsed pit. These domed features often retain traces of charcoal sufficient for radiocarbon dating (Holdaway et al. 2002, 2005).

Hearths within a given study location are surveyed and their potential for charcoal is estimated. The condition of hearths varies both within and between survey units. The present condition of the hearths is assessed using a qualitative visual assessment of the degree of hearth stone dispersion developed by Dan Witter. This protocol assigns hearths to one of five categories: partially exposed, intact, disturbed, scattered and remnant. Hearths are described as partially exposed when a portion of the hearth is still buried by sediment. Intact hearths are fully exposed with hearth stones forming a tight cluster. Disturbed hearths are those with dislocated hearth stones, but evidence of clustering, scattered hearths no longer retain a cluster of hearth stone, while the
presence of remnant hearths is indicated by a ring of dispersed hearth stones (Holdaway et al. 2005, Fanning et al. 2009a).

In most instances a number of surveyed hearths are in a state of preservation likely to provide sufficient quantities of charcoal to produce an age determination. A sample of these hearths is then selected and excavated for charcoal dating. Importantly, multiple age determinations are obtained for hearths within each sampling location, thus enabling an understanding of occupation history through time (Holdaway et al. 2002, 2005).

As noted, it is not possible to directly link artefact scatters and hearth features to the same occupation. Hearths do not occur in the absence of stone artefacts, but artefact scatters are found without the presence of hearths. This means that there were likely occupation events that left no datable record, however, the large number of hearths used to establish occupation chronologies and the resolution in which radiocarbon can be interpreted does provide a very useful measure of the general chronology of place use within the “envelope of time” established through sediment dating (Fanning, 2002).

4.1.2 Flake Stone Survey and Analysis

To investigate surface assemblage variability, the boundaries of artefact visibility within a geomorphological unit are then marked through micro-geomorphic mapping. The criteria for establishing these boundaries, and therefore areas of artefact exposure that will be analysed, help to control for factors that could potentially bias the sample
of assemblage variability such as vegetation and sediment cover or surfaces slopes steep enough to result in size sorting (Fanning and Holdaway 2002, 2004). Artefacts within these areas of visibility are then surveyed, either individually (piece proveniencing) or through the use of a 1x1 meter grid system. Point provenience information is preferred for areas with low to medium densities and for smaller areas. In order to survey large dense scatters quickly, however, a grid of 1×1 meter squares is occasionally established over the survey area using tapes and predetermined coordinates with a total station. A systematic sample of the squares within the grid is then selected for analysis. The coordinates of each square to be sampled are recorded with a total station. The use of a systematic grid helps to provide a good representation of the true distribution and density of artefact variability across a surface.

All artefacts located, either individually or by grid sampling, are checked for maximum clast length. Only artefacts with a maximum dimension of greater than or equal to two centimetres are recorded, as artefacts smaller than this are susceptible to water transport (Fanning and Holdaway 2001a). Those artefacts meeting this size requirement are marked with a nail. Artefacts are then analyzed by a team of two people; one person analyses the attributes of the artefact following a large recording protocol (Appendix One) while the other records this information into a palmtop computer running specialized data-entry software (McPherron and Holdaway 1999). In accordance with the wishes of Aboriginal Traditional owners, once analysed each artefact is immediately returned to the location in which it was found.
Figure 4.1: The Western NSW Study Region and Location of WNSWAP Study Areas Described in the Text.
4.2 Study Areas and Assemblages

Over the past 13 years, these techniques have been applied to a large number of study locations distributed throughout western NSW (Figure 4.1). As a result, a database totalling well over 170,000 individual data records for flaked stone artefacts has been accumulated.

Comparison of the chronologies (i.e. radiocarbon and OSL determinations) for different study locations demonstrates the complex nature of the surface archaeological record. As described in the previous chapter, landsurface age and geomorphic history play a crucial role in determining the total time span represented by the artefact scatters and heat-retainer hearths found on a given surface. Assemblages from different surfaces reflect different amounts of archaeological accumulation. Nearness in space does not necessarily equate to nearness in time because adjacent landsurfaces often differ markedly in age (Fanning 2002; Fanning and Holdaway 2002; Holdaway and Fanning 2003).

In contexts with recent erosion and deposition (e.g. alluvial valley systems), age determinations both for the landsurface and for pit hearth features exposed on that surface are relatively recent. As discussed previously, the sedimentary records within these areas frequently display unconformities where portions of the depositional history have likely been removed as a result of high magnitude flooding. These erosional events not only removed large amounts of sediment, but also the archaeological record that has accumulated in these places. As a consequence, the record that is available to study in these locations reflects accumulation that has
occurred since the most recent high magnitude, erosional episode (Fanning et al. 2008). In contrast, more stable landsurfaces, for example alluvial terraces, hillslopes and upland locations reflect a much older record. In fact, cosmogenic dating of many upland contexts has indicated that the archaeological records available for study on these surfaces generally reflect accumulation over the entire course of human occupation of the Australian continent (Fanning et al. 2008).

The results of these studies indicate that even though there is great similarity in the appearance of artefact scatters throughout the regions of western New South Wales, because of the unique geomorphological history of each location, they preserve very different records of the prehistoric past. Through these efforts a unique record of assemblage variability and occupation chronology within the arid zone is established. Each of the study locations used in this thesis is described below.
Figure 4.2: Stud Creek, Sturt National Park. Left; Map of Sturt National Park and Stud Creek study location. Right; Map of Stud 1, Stud 2 and Stud Systematic.
4.2.1 Sturt National Park

The Stud One, Stud Two, and Stud Systematic Survey areas are located on the valley floor of Stud Creek in Sturt National Park about 25km east of the town of Tibooburra in far north-western New South Wales (Figure 4.2). They were recorded by WNSWAP between 1996 and 1998. Stud Creek drains a roughly circular 30 km$^2$ catchment in Cretaceous sedimentary rocks of the Grey Range. The predominate stone raw material available in the area is silcrete, which can be found in outcroppings and associated boulder mantels along mesas and escarpments surrounding the creek and in gibber pavements found along hillslopes. The valley floor contains alluvial fills of late Pleistocene to Holocene age into which the creek has incised (Holdaway et al. 2000). It is on these alluvial fills that hearths and artefacts are exposed. OSL age determinations for the sediments upon which these artefacts are lagged indicate that the majority of artefacts are on surfaces no older than 2000 years. The Stud One, Stud Two and Stud Systematic sampling areas relate to three separate approaches to artefact recording along Stud Creek (Holdaway et al. 2002).

Stud One

The Stud One sampling area (Figure 4.2) relates to an intensive survey of artefact concentrations completed in 1996. The aim of this study was to develop a detailed sample of the surface record in order to relate variation in artefact density and variability to land surface type. To accomplish this, every artefact greater than two centimetres in maximum dimension within the survey area was recorded. These efforts resulted in data records for 20,066 silcrete artefacts.
**Study Two**

Survey at Stud Two (Figure 4.2) was directed at examining within-unit artefact variability and was accomplished by analyzing all artefacts within a single geomorphologically identified landsurface type, in this case “eroding valley margin.” These efforts resulted in a record of 24,202 silcrete artefacts.

**Stud Systematic**

In order to obtain a record of artefact variability for a much larger spatial area within the Study Creek study area, Stud Systematic comprised a north-south and east-west grid of a 120,000 m² area adjacent to the Stud One and Two sampling areas (Figure 4.2). Recording within this area was systematically completed for every fifth grid, resulting in a seven percent sample of the area. These efforts resulted in data records for 7939 silcrete artefacts.

The remains of 72 heat retainer hearths were identified within the Stud Creek sampling areas, 28 of which yielded sufficient charcoal to obtain a radiocarbon determination. Age determinations from the hearths indicate a record spanning from approximately 1630 to 220 BP. Bayesian statistical analyses indicate that hearth ages fall into two distinct phases of hearth construction, separated by a 200 to 300 year gap where no detectable hearths were created (Holdaway *et al.* 2002).
Figure 4.3: Assemblage Locations within Fowlers Gap Study Area.
4.2.2 Fowlers Gap

The Nundooka, Mulga Dam, Fowlers Creek, Sandy Creek, Sandstone Tank, Faraway, and Nuntherungie sampling locations are located on the Fowlers Gap Arid Zone Research Station, a pastoral lease of approximately 39,000 hectares run as a research facility by the University of New South Wales 250 km south of Stud Creek (Figure 4.3). They were recorded in three separate field seasons by WNSWAP between 1999 and 2001. A wide variety of stone raw material sources can be found throughout the area. These are quartz, silcrete and quartzite which occur in outcrops associated with the barrier ranges and on gibber pavements and in beds of dry creek lines found throughout the area. There are no permanent sources of water in the area, but instead a multitude of different creek lines and other ephemeral water features that hold water following rain (Holdaway and Fanning 2003).

Nundooka

The Nundooka (ND) sampling area is located on a bouldery floodplain surface along the valley floor of Sandy Creek (Figure 4.3). Archaeological survey was completed for a 200 by 50 meter north south trending portion of a terrace veneered with fine-grained alluvium adjacent to a waterhole referred to by Jansen (2001) as Murder Pool. This waterhole is dry most of the time, but holds water for several months after most stream-flow events (Holdaway and Fanning 2003).

Jansen (2001) developed a flood history within the gorge extending back nearly 4,000 years. The alluvium into which hearths and artefacts were deposited accumulated as a slackwater deposit during a flood event which occurred around 1100 BP. Fourteen
hearth remains were excavated at ND, with eight samples submitted for dating. Results indicate two groups of determinations one with calibrated age ranges younger than 525 cal. B.P. and a second with ages older than 525 cal. B.P. (Holdaway et al. 2005). No hearths have ages older than 800 years. An artefact assemblage comprising 2941 quartz artefacts and 2127 silcrete artefacts was analyzed from ND. Quartz is available close by as stony desert gibber cobbles and along the banks of Sandy Creek. Silcrete can be found within the gibber pavements on the hillslopes above the study area as well as in outcroppings located a few kilometres from ND (Shiner et al. 2005).

Fowlers Creek

The Fowlers Creek (FC) sampling location is a 200 by 150 meter deflated surface situated on a quartz gravel terrace on the western side of Fowlers Creek (Figure 4.3). Quartz is available in the immediate vicinity in the form of extensive gibber pavements and as cobbles from the Fowlers Creek channel bed. Mapping and analysis of artefact scatters distributed throughout the survey area resulted in data records for 4596 quartz and 267 silcrete artefacts (Holdaway and Fanning 2003).

Three separate hearth clusters were identified within the vicinity of FC during a preliminary survey in 1999, however, high magnitude rainfall events during the summer of 1999-2000 caused considerable damage to one of the hearth clusters near the centre of the survey area. In the interest of salvaging these threatened hearths, excavation concentrated on this single cluster. An additional two hearths away from this main cluster were also excavated to gain an appreciation of the spatial relationships of the survey area. Finally a third hearth cluster along the Fowlers Creek channel was excavated. Combined these efforts resulted in 16 hearth age
determinations, ranging between modern to 6202 cal B.P. (Holdaway and Fanning 2003).

Five distinct groupings of hearth age determinations were identified amongst the hearths excavated at FC. The Oldest relates to a single determination sometime around 6000 years ago. The second grouping relates to eight determinations ranging from 4450 to 3450 cal B.P. and the third relates to two hearths dating to the end of the 2\textsuperscript{nd} millennium cal B.P. The fourth and fifth distinct grouping of hearth determinations relates to five hearths that span the first millennium cal B.P. (Holdaway and Fanning 2003).

\textit{Sandstone Tank}

The Sandstone Tank (ST) study area relates to an approximately 300 meter stretch of a shallowly incised dendritic creek line which drains to an early 20\textsuperscript{th} century earthen dam upon a broad upland surface (Figure 4.3). Quartz is available in gibber pavements and within the creek line. Artefacts and pit hearths are distributed along a 100 meter long portion of the northern bank of the creek line along the northernmost stretch of the sampling location. Mapping and analysis of artefact scatters distributed throughout the survey area resulted in data records for 1541 quartz and 96 silcrete artefacts (Holdaway and Fanning 2003).

Preliminary investigations in 1999 identified a large number of hearths, however, substantial flooding that occurred shortly thereafter damaged, buried and removed many of these, and in the 2001 season only a small number could be relocated. Only three of these were in a state of preservation sufficient for an age determination. A
fourth determination was obtained for charcoal buried beneath hearthstones exposed in the creek bank. Age estimates range from 530 to 200 B.P. (Holdaway and Fanning 2003).

*Mulga Dam*

The Mulga Dam (MD) sampling area is situated along a narrow strike belt on moderately to gently dipping Nundooka Sandstone (Figure 4.3). The west-facing footslopes are mantled with a veneer of Quaternary wind-blown sand, where dense scatters of artefacts and hearths are exposed. The survey location is a 300 by 100 meter scalded area running north-south along the eastern bank of Sandy Creek approximately three kilometres northwest of the Sandstone Tank sampling location. Quartz and Silcrete cobbles are exposed on channel bars of Sandy Creek and within patches of gibber pavement distributed throughout the area and along hillslopes immediately to the north of the survey area boundaries. Mapping and analysis resulted in data records for 2702 quartz and 1351 silcrete artefacts (Holdaway and Fanning 2003).

A total of 12 hearths were excavated within the MD survey area six of which yielded quantities of charcoal sufficient for dating. Age determinations for the MD hearths ranged between 200 BP to 1150 BP. Two distinct groupings of hearth age estimates were identified, the first ranges between 200-500 years BP while the second ranges between 800-1100 years BP (Holdaway and Fanning 2003).
Sandy Creek

The Sandy Creek (SC) sampling area is located along the proximal end of the Nelia Creek flood-out, about one kilometre from Nelia Dam, in the south-eastern corner of Fowlers Gap Station (Figure 4.3). The area comprises a long narrow alluvial fan confined between bedrock spurs. The alluvial fan surface contains extensively scalded areas with abundant scatters of flaked stone and associated pit hearths. Quartz and silcrete is available in the area through extensive cobble bars in the creek bed and gibber pavements distributed along the hillslopes on either side the floodplain. Mapping and analysis of artefact distributions from four extensively scalded areas distributed across the 1400 meter section of the floodplain resulted in 3222 quartz and 1443 silcrete artefacts (Holdaway and Fanning 2003).

An abundance of hearths are more-or-less evenly distributed across the entire 1400 meter sampling area. A total of 21 hearths were noted to be in a state of preservation likely to yield an age determinant and were excavated. Of these 13 were submitted for dating. Age determinations for several of these hearths were sufficiently modern to be unreliably dated through radiocarbon, while the maximum age determination was 1350 BP. These values indicate that hearth construction at the SC sampling area ranged between a period beginning around 1300 calibrated years BP through to sometime during the last 200 years (Holdaway and Fanning 2003).

Faraway

The Faraway (FW) sampling area comprises a 300 meter section of the exposed alluvial surface along the north bank of Gum Creek (Figure 4.3) within the Faraway
Hills in the south-central portion of Fowlers Gap Station. Quartz can be obtained from gibber pavements distributed throughout the area (Holdaway and Fanning 2003). Artefact mapping and analysis resulted in data records for 1453 quartz and 228 silcrete artefacts. Nine hearths were excavated within the area, but poor preservation resulted in no age determinations for this study location.

*Nuntherungie*

The Nuntherungie (NN) sampling area is located along an approximately 825 meter long section of heavily eroded valley floor margin of Homestead Creek (Figure 4.3). Artefacts and the remains of deflated pit hearths are distributed across gently sloping hard subsoil surfaces bounded by erosional gullies draining into the deeply incised main channel of Homestead Creek (Holdaway and Fanning 2003).

Quartz and silcrete are available within the immediate area in the form of gibber pavements and cobbles within the creek bed. Artefacts were mapped and analysed within four areas of high visibility distributed on either side of the creek channel. This resulted in data records for 1299 quartz and 286 silcrete artefacts (Holdaway and Fanning 2003).

While a large number of hearths were present within the area, the poor state of preservation meant that few hearths yielded quantities of charcoal sufficient for dating. The four hearths for which age determinations were obtained come from an area directly in the centre of the study area. Three hearth determinations are clustered around 500 cal BP, while the fourth is around 850 cal BP (Holdaway and Fanning 2003).
Figure 4.4: Paroo-Darling National Park and Study Assemblages.
4.2.3 Paroo-Darling National Park

The Charlton Waterhole (CW) Round Hill (RH) and North Peery assemblages are located within the 94,000 hectare Paroo-Darling National Park in western NSW approximately 320 km northeast of Broken Hill (Figure 4.4). They were recorded by WNSWAP in the winter of 2002. High quality silcrete abounds in the area and can be found in outcroppings along mesas and other upland features as well as on extensive gibber pavements and along cobble bars within dry creek lines. The combination of Peery Lake (which collects runoff from large western catchments and overflow from the Paroo River and is known to retain water for months to years once full), numerous creek lines which retain water following rain, and the presence of permanent artesian mound springs along the shoreline of Peery Lake ensure that water is in relative abundance within the park (Holdaway et al. 2002).

Charlton Waterhole

CW is located near a deep pool along the north-south trending Peery Creek which connects with the Paroo River south of Peery Lake (Figure 4.4). The pool holds water for weeks to months following rain. Artefact scatters and associated hearths are distributed along the eastern bank of the creek. A survey of an area approximately one km x 200 m in size recorded 210 hearths (from which a sample of nine were selected to obtain age estimates) and 5016 flaked silcrete artefacts (Holdaway et al. 2006:23). Age determinations from the hearths indicate a record spanning from approximately 1800 to 350 BP with three distinct phases of hearth construction (Holdaway et al. 2006:20-23). The majority of lithic artefacts were produced from locally abundant silcrete cobbles collected from the bed and banks of Peery Creek and adjacent gibber
plains although some silcrete was possibly imported from outcrops in the surrounding table lands (Holdaway et al. 2002).

Round Hill

The RH sampling area is situated around the silcrete outcrops and associated boulder covered slope mantle found along a prominent high point a few kilometres northwest of Peery Lake (Figure 4.4). Flaked stone artefacts are distributed across the nearly flat duricrust surface at the top of the hill and down the adjacent slopes (Holdaway et al. 2006:47-55). Artefact density varies considerably with greater densities clustered around silcrete outcrops. Three separate sampling areas totalling 414 m² were selected to ensure the inclusion of a variety of artefact densities. A total of 3006 silcrete artefacts were analyzed and no hearths were located. The absence of datable hearths precludes establishing a chronology of occupation, but the relatively stable geomorphic location (a low relief residual hill) most likely ensures a record of occupation much longer than the CW location (Holdaway et al. 2002).

North Peery

The North Peery sampling area is located along the north-western foreshore of Peery Lake (Figure 4.4). The area comprises a 3,500 meter area of gibber pavement, sediment islands and patches of erosional exposure situated within the proposed boundaries of a car park and day-use area. Artefact survey of the area noted distributions of flaked stone artefacts within erosional exposures, the majority being concentrated along the southern end of the survey unit between two vehicle tracks. Silcrete is locally available within the area in the form of dry creek channels to the east and west of the survey area and within gibber pavements within the immediate
survey boundaries. A total of 1574 silcrete artefacts were analysed. A single radiocarbon determination for a hearth located in the south-western margin of the survey area yielded an age of 357±46 BP (Holdaway et al. 2002).

4.2.4 Burkes Cave

Burkes Cave itself is a small rockshelter with a shallow rocky floor situated adjacent to a small creek in an upland valley of the Scopes Range (Figure 4.1), 90 kilometres east of Broken Hill, excavated by Harry Allen in (1972) for the completion of his doctoral study. Allen thought it unlikely that this would yield the deeply stratified deposit he was looking for, and instead chose to excavate a 2.88 m\(^2\) area on the terrace immediately outside the rockshelter, attaining a maximum depth of 1.7m (Allen 1972:143-144). Quartz gibbers can be found in the immediate vicinity of the cave, but the nearest known source of silcrete is along the eastern flank of the range several kilometres from Burkes Cave (Shiner et al. 2005, 2007).

The 4302 silcrete and 1934 quartz artefacts utilized here are a sample of the approximately 20,000 artefacts recovered by Allen (1972). The assemblage is housed in the Australia Museum in Sydney where every piece >20mm in maximum dimension (the data presented here) was subsequently reanalyzed in 2001 by Justin Shiner and Simon Holdaway. A single radiocarbon determination on charcoal retrieved from immediately below the artefact bearing layers by Allen indicates that the majority of artefacts were discarded in the past 2000 years (Allen 1972).
Figure 4.5: Pine Point Langwell Study Area and Study Assemblages.
4.2.5 Pine Point and Langwell Stations

The Conservation One and Three, Kars One and Two, and Silcrete Quarry One sampling locations are located within two adjoining pastoral leases, Pine Point and Langwell Stations 50 km south of Broken Hill (Figure 4.5). They were recorded by Justin Shiner in 2001 and 2002 as part of his doctoral research (Shiner 2004). These locations are characterized by low relief and are positioned within a transitional zone between the foothills of the Barrier Range to the north and the Quaternary sandplains of the Darling River floodplain to the south. Quartz is available throughout the area while the availability of silcrete is largely restricted to outcrops and gibber pavements along ridge tops, but is occasionally found in the quartz gibber pavements and gravel bars within the channel beds of dry creeks (Shiner 2004, 2006). There are no permanent sources of water in the area, but instead various creek lines and ephemeral water features that hold water following rain. Pine Creek is the largest watercourse in the study area, with the smaller Rantyga Creek joining Pine Creek on Langwell Station. Smaller ephemeral creeks and drainage lines that flow into small swamps and internal drainage basins are distributed across the area (Shiner 2004, 2008).

Conservation One and Three

The CN1 sampling area is located on an extensive scalded area along a terrace on the north bank of Pine Creek approximately 600 metres downstream of the confluence with Rantyga Creek (Figure 4.5). Quartz is available in the immediate vicinity of the sampling area in the form of gibber pavements and in dry creeklines and silcrete can be found along ridge tops approximately 9 kilometres to the northeast or along low lying hills seven kilometres to the northwest, though it is also found in limited
quantities in the gibber pavements and creeklines surrounding the area. A total of 19,355 m² were surveyed yielding 7270 quartz and 1427 silcrete artefacts.

The CN3 sampling location relates to an approximately 800 metre long area along the north bank of Pine Creek approximately one kilometre east of CN1 (Figure 4.5). Conditions of CN3 are similar to that of CN1, however, areas of scalding and therefore artefact exposure are more discontinuous. A total of 4139 quartz and 689 silcrete artefacts were mapped and analysed over an area of 12,813 square metres.

A five kilometre long section of valley floor, parallel to Pine Creek, yielded 87 heat-retainer hearths, 12 of which were sampled. Age estimates ranged from approximately 1750 to 250 cal. BP, with four separate periods of hearth construction (Shiner 2004, 2006).

Kars One and Two

The Kars One (KZ1) sampling location comprises a two kilometre long area situated on either side of Rantyga Creek, approximately three kilometres from the confluence with Pine Creek (Figure 4.5). Stone raw material is available in the form of gibber pavements which contain large quantities of quartz and rare cases of silcrete. The creek channel is currently choked with sediment, but it is possible that stone cobbles were exposed and therefore available for use at different points in the past. Stone artefacts were recorded on a total of 21 separate scalded areas distributed within the sampling area. These features comprised 11,795 square metres of exposed surface and resulted in the analysis of 2177 quartz and 1427 silcrete artefacts and 10 heat-retainer hearths were recorded.
The Kars Two (KZ2) sampling location is an 800 metre long area along the western bank of Rantyga Creek. Approximately 1.5 kilometres upstream of the confluence with Pine Creek in the Kars land system (Figure 4.5). Artefact distributions were mapped on discontinuous scalded areas comprising over 7203 square metres and resulting in data records for 6956 quartz and 4073 silcrete artefacts.

Thirty five hearths were recorded on both sides of Rantyga Creek along a two kilometre transect encompassing the KZ1 and KZ2 sampling areas, four of which were sampled. Age estimates range from 516 BP to 2004 BP (Shiner 2008).

*Silcrete Quarry One*

The Silcrete Quarry One (SQ1) sampling area is located in the residual foothills of the Barrier Range six kilometres north of the confluence of Pine Creek and Rantyga Creek (Figure 4.5). This location consists of a 292 m² area along a silcrete outcropping and associated boulder mantle. Shiner (2004, 2006) analyzed 4151 silcrete artefacts but no hearths were found within the survey area. Worked silcrete comprised the overwhelming majority of the assemblage and only these artefacts are analyzed here. While there are no recorded hearths within the area, the record of its utilization is likely to be longer than that of the more geomorphologically active CN and KZ sampling locations (Shiner 2004, 2006).
4.3 Conclusion

This Chapter has outlined the methodology developed by the Western New South Wales Archaeological Programme to place deflated surface assemblages within their proper chronological perspective. Geomorphological and geophysical (OSL) techniques were used to date the surfaces upon which stone artefacts and hearths now lie. Radiocarbon dating of hearths from within these assemblages then helped to develop a history of human occupation represented on each of these dated surfaces. The many assemblages described reflect over 13 years of research to contextualize archaeological assemblages distributed throughout western NSW. The next chapter will discuss the implications of this record for exploring the long-term variation in Aboriginal place use and how the patterning in these lithic assemblages can be utilized to address the anomaly that exists between the demanding environmental context of the region and the informal lithic technology that was practiced there.
Chapter Five
Time Averaged Assemblages and Technological Organization
5.1 Introduction

The objective of this thesis is to determine whether the unretouched flakes and informal cores that dominate the Australian record denote a casual approach to technology or whether instead the perception of simplicity is an artefact of the techniques archaeologists use to study stone artefacts. Lithic analysts seek to use the production, use and discard of stone tools to study prehistoric mobility and land use. However, the retouched tools and formalized cores that are the main focus of current analyses are not well represented in western NSW. To determine the strategies that Aboriginal populations utilized to adapt to the sparse and unpredictable environment of the arid zone therefore requires the development of techniques beyond those that currently predominate in lithic analysis.

Stone artefacts occur as expansive surface deposits in western NSW. In the preceding two chapters, I outlined the formational history of these deposits, summarising approaches developed by the Western New South Wales Archaeological Programme, and describing the large suite of surface assemblage data that are now available for study. This chapter outlines the interpretive potential of time-averaged assemblages (sensu Stern 1994a, 1994b) like those from western NSW and considers the theoretical concepts of relevance for inferring behavioural dynamics from what by first impression is a static record of a timeless past. The development of a perspective with which to explore Aboriginal technological organization and land use with the largely informal lithic assemblages of western NSW will then be presented in the chapters that follow.
5.2 Interpretive Potential of Time-Averaged Deposits

The preceding chapter outlined how the complex formational histories of the deflated surface deposits of western NSW reflect the accumulation of cultural material from many different behavioural events onto a single surface. Because they reflect the activities of different people, during different occupations, likely engaged in unrelated activities, the remains of these time-averaged deposits do not lend themselves to interpretation within a synchronic settlement system (Holdaway and Fanning 2008; Holdaway et al. 2008a, 2008b; Holdaway and Wandsnider 2006). In order to make inferences about the processes responsible for the formation of the archaeological record like that in western NSW, a perspective capable of accommodating time-averaged assemblages formed over the long-term is needed (Orton 1982; Wandsnider 1996).

A time-averaged record can be accommodated by viewing the archaeological landscape not as the product of short-term occupations or single function locations, but instead as the outcome of differential place use through time (e.g. Holdaway and Wandsnider 2008; Holdaway 2001, 2008b; Shiner 2003, 2004, 2008; Stern 1994a, 1994b; Wandsnider 2006). From this perspective, individual components of the landscape have complex occupational histories that reflect their use in repeated and varied activities of differing frequency, intensity, and duration. Archaeological views of short-term behaviours are in most cases gone. What the record does offer is the material outcome of behavioural systems operating at scales imperceptible in the present. This is a vantage that can only be afforded by the passing of time (Holdaway and Wandsnider 2006).
The interpretive power of archaeological deposits comes from the vantage they give onto the deeper structure of human organization. Just as single observations have limited utility for deciphering underlying statistical trends, observations of single points in the past have limited utility for understanding higher-order determinants of human behavioural organization. Deeper patterns require repetition to develop; time transgressive assemblages present an important resource through which such patterning can be studied.

Schlanger (1992, 1991, 1990, 1988) has elaborated on this value of time transgressive patterning through the concept of Persistent Places. For her, Persistent Places are those locations repeatedly used during the long-term occupation of a region (1992:97). With due allowance for the processes of artefact deposition, peaks in artefact density may indicate places that were subject to greater human presence through time while the lower densities of material between these places reflects the persistent use of the landscape in general. Those portions of the landscape subject to repeated human occupation likely possessed certain qualities that fostered their continued use. While the manner in which these places were used may have changed through time, their repeated occupation speaks to their extended desirability.

Using the concept of Persistent Places, patterns in the prehistoric use of the arid zone can be examined. People move about the landscape, leaving a trail of discard in their wake. The time-averaged patterns that emerge therefore indicate variability in the long-term structure of land use.
5.3 Western NSW Occupation Histories

As previously noted, the archaeological record of the arid zone is concentrated within alluvial valley systems. While upland surfaces have comparable visibility and great antiquity, it is the markedly younger surfaces within valley systems where artefactual remains are found in greatest abundance. Within these valley systems there is considerable variability in artefact density. Some areas reflect diffuse scatters and isolates, but there are also dense concentrations of flaked stone and hearths in areas that were repeatedly targeted for use. The repeated use of these areas indicates that they continued to attract human occupation through time.

Heat-retainer hearths reflect individual occupations. Hearths accumulate in clusters but there is little to suggest that the occupants who made hearths at any one time were aware of the existence of the people who made hearths during previous occupations. Hearths of different age are routinely found side by side with no evidence of reuse. In effect, individual hearths appear to be one-offs rather than the long use features subject to continued use and investment found in other contexts (e.g. slab lined hearths in the Wyoming Basin, Smith and McNees 1999).

The observation that hearths of multiple different ages are routinely found upon a single geomorphological surface (e.g. Figure 5.1) does not imply continued occupation through time or the stability of a long-term settlement system. Instead, multiple distinct occupations are conflated onto one surface. People came and made hearths at various times in the past, presumably when these locations were desirable for human occupation. Hearths are often concentrated near to ephemeral water
sources indicating times when water and resource abundance drew people to these areas.
Figure 5.1: Example of Hearths Clustered Upon a Single Geomorphological Surface (Paroo-Darling National Park). Dots indicate the location of hearths and text boxes contain radiocarbon determinations for those hearths from which sufficient charcoal for radiocarbon dating could be retrieved. Hexagons indicate locations of OSL sediment sampling, with text boxes containing the age determination for the sedimentary sequence for each location. Combined, OSL dates the surface; hearth chronologies date the occupation history upon that surface.
Figure 5.2: Calibrated Radiocarbon Determinations from Dated Hearths in Western NSW (Holdaway et al. 2005 Fig. 9). Gray bar indicates gaps in hearth construction related to the Medieval Climatic Anomaly.
The large number of hearth radiocarbon determinations from the individual WNSWAP study areas indicates the nature of the long-term occupation within the region. There are numerous gaps in the distribution of the age determinations through time (Holdaway et al. 2002, 2005). However, because hearths predating and post dating these gaps are found upon the same geomorphological surface, breaks in hearth chronologies are unrelated to contemporary or past erosion. Instead, gaps indicate periods when hearths construction, and by extension human occupation, was dramatically reduced if not ceased entirely. The structure of occupation within western NSW during the late Holocene was not continuous, but varied as portions of the landscape were occupied, abandoned, and then occupied once again at a later date (Holdaway et al. 2002, 2005).

These gaps often correlate with worldwide climatic instability. At Fowlers Gap, time series analysis using plots of the summed probability distribution for hearths shows a pattern of peaks and gullies that correlate with variation in the sea surface temperatures from the Mindanao sea core (Graham et al. 2007; Stott et al. 2006) although with a 50 year lag (Holdaway et al. 2008a, 2009). Gaps at Stud Creek show a similar pattern, but in this instance correlate with the Medieval Climatic Anomaly (MCA, AD 900–1200) (Holdaway and Fanning 2007; Holdaway et al. 2002). These results suggest that Aboriginal land use in western NSW was periodically reorganized in the face of climatic deterioration where conditions of increased aridity limited the ability of Aboriginal populations to utilize some portions of the landscape.

The dynamism offered through the contextualization of these time-averaged assemblages provides a perspective that is lacking in many interpretations of
Aboriginal organization (Fanning et al. 2007). The perception (e.g. Lourandos, 1980, 1983, 1985) that Aboriginal occupation of western NSW was more or less continuous from the late Holocene onwards reflecting long-term stability in human-land relationships and a move towards greater sedentism is not correct. Variability in lithic patterning within the region suggests a similar dynamism. While the dearth of formalized artefact and core morphologies has led to the perception of a remarkable uniformity, analysis of assemblage composition at different locations indicates considerable variability.

A main source of this variation relates to differences in the intensity and duration of the different occupations. Areas with a greater propensity for relatively long occupations show more intensive core reduction, greater use of local raw materials and a higher rate by which flakes were transformed into retouched tools. Areas subject to shorter occupations, on the other hand, likely experienced less intensive raw material use and are apt to show a greater reliance on non-local materials (Elston 1990; Holdaway et al. 2004). Repeated occupation through time can also serve to modify assemblage composition as previously worked materials are further reduced (Shott 2008). Thus, variability between locations is an outcome of the variable history of occupation of these places through time.

A further indication of dynamism concerns inter-assemblage variation between areas separated by very short distances as well as intra-assemblage variability within single locations. For example, analyses of assemblages from Stud Creek in Sturt National Park and Pine Creek at Pine Point Langwell indicate that high density artefact deposits located only a few hundred meters apart display considerable diversity with
common analytical indices. Even through these areas share essentially the same contextual variability, patterning in core reduction intensity displays a clear divergence where some areas have high flake to core values while others do not (Holdaway et al. 2004; Shiner 2008). Similarly, analyses from the Fowlers Gap sampling location known as ND suggest that artefacts within a single assemblage derive from a number of different occupations of varying duration (Holdaway et al., 2008). Here, patterns in flake to core ratios and retouched tool frequencies between local materials and those that must have been brought in from elsewhere (i.e. fine grained silcrete) are inconsistent, in that it is the local materials that have been utilized somewhat more intensively (Holdaway et al. 2008b).

The result of these observations is that the distributions of lithic remains that are available to study are not likely to be the outcome of a stable system of settlement that played out largely unchanged, even during periods where there are no measurable breaks in hearth chronologies. That time averaging at a millennial scale was insufficient to produce what amounts to a single behavioural uniformity (sensu Shiner 2008) within these assemblages has further implications for general trends in place use within the region.

Repeated and frequent overprinting over an average of two thousand years should limit the ability to perceive the effects of disparate behaviours over short distances. Binford makes the same observation for coarse grain assemblages associated with long-term residential bases (Binford 1982). That a modal pattern does not emerge in any of these assemblages suggests that occupations were both generally of short duration, meaning Aboriginal populations were highly mobile, and that place use was
infrequent. The lack of evidence for hearth re-use or caching behaviour supports these findings. People were unaware of previous occupations and there is little evidence that they planned to return.

In effect survey patterning displays dynamism similar to that indicated by the hearth chronologies. This variability, however, likely reflects shorter term shifts in behaviour and land use than those recognized through the resolution afforded by radiocarbon. As discussed in Chapter Two, the unpredictability with which the environment changed, especially as it relates to the availability and absence of water, existed in the short-term. It is likely that the immediacy of these changes was of equal if not greater significance to the strategic choices made by individual Aboriginal populations as they conducted their daily lives.

5.4 Summary

Up to this point, the chapters in this thesis have provided the backdrop from which I will approach the anomaly that exists between the apparently casual nature of Aboriginal lithic technology and the demanding contextual factors of the region in which the technology was developed. The information presented is in essence a compendium of the findings obtained through over 13 years of research by the Western New South Wales Archaeological Programme.

Through this review, I have outlined the character of the artefactual remains available in the region, the demanding environment found there and ethnographic observations that suggest that mobility, fluid group composition and territorial permeability were
key strategies through which historic Aboriginal populations coped with these conditions. The record that is available for study is dominated by surface assemblages that as a consequence of their unique occupational histories do not reflect what can be interpreted as site types within a settlement system, but instead represent time-averaged accumulations of variable age. The approach developed by WNSWAP has provided occupational histories for assemblages distributed throughout western NSW and has resulted in data records for over 123,000 stone artefacts.

Observations of the long-term patterning in these assemblages present a picture of dynamism. Hearth chronologies show discontinuities in occupation that correlate with world climatic events and though stone artefact assemblage contents continue to be dominated by unretouched flakes and informal cores, there is considerable variability in assemblage composition over relatively short geographic distances and between different material types within individual locations.

Contrary to a static record, these assemblages exhibit a complex organization in the past. The challenge is to make the connection from these long-term histories of place use to an exploration of the means by which the populations who created this highly variable historical record situated themselves within the greater landscape. The goals of this thesis go beyond questioning whether or not prehistoric Aboriginal populations were indifferent to their lithic technology to the larger question of how assemblages dominated by unretouched flakes and informal cores can be interpreted to illustrate dynamic organizational systems? Just as the previous research of WNSWAP has exposed the erroneous interpretations of long-term continuity that result from taking the surface archaeological record at face value, a similar dynamism of a different sort
awaits discovery within the patterning displayed in the morphologically simple lithic technologies of the region.

5.5 The Study of Lithic Technological Organization

Lithic analysts investigate the manner in which prehistoric toolmakers and tool users organized their lives and activities and how understanding of this organization can be used to understand past adaptation. These goals are subsumed under the rubric lithic technological organization.

The organization of technology (Nelson 1991) reflects different strategies by which people manipulate material culture to adjust to on the ground conditions. In effect, variability in the means of “making, using, transporting, and discarding tools and the materials needed for their manufacture and maintenance” (Nelson 1991:57) is responsive to the interplay between behavioural organization observed at a landscape scale and the structure of the environment. Differences in such factors as the distribution of the critical resources through which life was sustained, along with social norms, traditions and a host of other factors, influenced how populations positioned themselves and moved throughout the greater landscape. The nature of these systems and the physical and social conditions that structured their organization served both to inform and constrain the range of technological solutions that could be employed at any one point in the past. By studying variability in stone artefacts and assemblages, archaeologists establish a link between the material record and the organization of the past (e.g. Binford 1973, 1977, 1979; Bleed 1986; Kelly 88; Nelson 1991; Parry and Kelly 1987; Shott 1986; Torrence 1983).
Central to studies of lithic technological organization are the concepts of curation and expedience (e.g. Nelson 1991; Torrence 2001; Shott 1996; Odell1996; Andrefsky 2008; Bamforth 1986; Nash 1996). These terms relate to differences in the amount of investment and planning that went into lithic technology and they reflect a number of contextual factors affecting how people made and used artefacts.

The strategy of curation requires an investment for future use, as “tools are made in advance of anticipated use, are carried around in anticipation of use, and whose lives are prolonged so as to be continually ready for use “(Torrence 2001: 84). Curation facilitates technological solutions when materials might not be immediately at hand. In contrast, expedience refers to the opportunistic production of artefacts as needs arise with artefacts used and discarded all in one place (Binford 1977). These concepts have received much attention in technological studies because of their direct applicability to inferences about patterns of human mobility and land use (e.g. Bamforth 1990; Kelly 1983, 1988; Nelson 1991; Shott 1986; Torrence 1983).

Under conditions of high mobility, people face the dual challenge of being unable to predict with certainty when and where material needs may arise as well as having uncertainty about the availability of raw material for artefact production. These conditions favour the use of a strategy based on artefact curation where forms are carried between locations. In contrast, with greater sedentism, challenges due to the unpredictability of resources and materials are lessened. Where technological needs and raw material supply are predictable, a strategy of expediency is favoured, where artefacts are made on an as needed basis. These two strategies are situational alternatives reflecting the relationship between when an artefact is needed and when
the time and raw materials for its production are available. As Nelson (1991:64) states, “while curation anticipates the need for materials and tools at use locations, expediency anticipates the presence of sufficient materials and time.”

High group and individual mobility imposed considerable restraint on the range of suitable technological choices. Where artefacts are carried, limitation on the quantity of portable raw material promoted an emphasis on portability and efficiency which limits material waste and decreased the likelihood of failure. A strategy of artefact curation is thus generally associated with increased effort in production, design and selection. In contrast, under conditions of greater sedentism, an adequate supply of material was often more easy to facilitate meaning there was little difference between the time and place of raw material availability and the time and place of tool use. Therefore a strategy of expediency need not require the levels of investment associated with transported forms. Instead, the constraints imposed on a technology were simply those of sufficiency to meet the task at hand. The result was a greater range of suitable technological options and a de-emphasis on formalized artefact morphology (Parry and Kelly 1987). For these reasons, sedentism and a greater emphasis on expediency is often associated with profligate, less economic, use of stone raw material while mobility and greater curation is assumed to promote more parsimonious raw material usage. The constraints that different levels of mobility impose on the organization of technology serve as a basis for developing expectations about the material consequences of these strategies for different strategies of land use (e.g. Binford 1979, 1980; Nelson 1991; Wallace and Shea 2006).
Early applications of these concepts often viewed curation and expedience as formal qualities that could be identified archaeologically, hence it was common to differentiate between curated (e.g. formalized retouched tool forms and highly patterned core morphologies) and expedient (e.g. unretouched flakes and unstandardized core reduction) artefact types within lithic assemblages (e.g. Andrefsky 1991; Bamforth 1986; Kelly 1988; Parry and Kelly 1987). However, researchers are now beginning to take a more nuanced view of the curation concept.

Following Torrence(2001:84-5), curation does not relate to tools, neither their morphology, nor the attributes they might acquire, but instead to the anticipation of future needs, a definition close to Binford’s (1973) original formulation of the curation concept. Curation relates to a process that facilitated technological solutions when materials might not otherwise be immediately at hand. Curation cannot be observed directly in the archaeological record. Instead a proxy measurement is needed to properly ‘diagnose’ the operation of this process from the material remains that do remain for study. Artefacts are not curated or expedient, instead individual artefacts are subject to different degrees of curation. Artefacts are the medium through which curation is actualized. The process is external to the technology and its application is apt to vary in relation to a host of contextual factors.

Current applications of curation as process use the reductive nature of stone working meaning that artefacts are subject to a process of transformation from the time that an artefact is produced to the time that it enters the archaeological record (see Andrefsky 2008 and papers within), a phenomenon often referred to as the ‘Frison effect.’ For these studies, retouch intensity is the curation proxy of choice.
Shott (1989, 1996) discusses the methods needed for measuring lithic curation through retouch intensity (Shott 1989). He defines curation as the “practice of maximizing the utility of tools by carrying them between successive settlements” and measures curation as the “the realized utility of a tool” (1989:24). Utility is defined as “the value obtained through the use of a tool” (1989:24). Efforts to maximize the utility of tools result in extensive retouch as an artefact moves through its life-cycle (or use-life) with its edge being used, dulled, and resharpened. Artefacts can sustain only limited edge renewal, so retouch intensity can be measured relative to a point of exhaustion. A measure of curation is therefore expressed as the “ratio of realized to potential utility” (Shott 1989:24) which for flaked stone tools is theoretically represented as the inverse of the percentage of the original mass remaining on an artefact.

This proxy measure works quite well in some contexts. The problem, however, is that in other contexts there is little in the way of retouch. Western NSW is a prime example. Although some contexts dominated by unretouched flakes and informal cores are connected with increased sedentism others are not. The contextual factors associated with the environment of arid Australia almost certainly necessitate high mobility, but paradoxically lithic assemblages are dominated by traits associated with greater sedentism. Recent discussions of curation provide little help. While a strict dichotomy between curation and expedience is rejected, an emphasis on retouched tools labels unretouched forms either as expedient or of no value for investigating the effects of artefact curation. Is the dearth of retouch a clear sign that the curation process was not present, or is it instead a consequence of the proxy measure of the process not being well suited to the analysis of certain assemblages? While retouch is
a valuable measure for some assemblages, can curation exist in the absence of much retouch?

A number of researchers have noted the importance of lithic raw material availability in technological organization, since increased raw material abundance may serve to relax efforts towards artefact standardization and retouched edge refurbishment (Andrefsky 1994a, 1994b; Odell 1996; Parry and Kelly 1987). Parry and Kelly (1987:301-302) provide a good summary of these ideas relating ethnographic examples where hunter-gatherer groups who were highly mobile used informal lithic technologies:

These hunter-gatherers all appear to have access to abundant and widely distributed lithic materials, and they used these locally available materials to produce expedient flake tools. Paradoxically though it may seem, such cases of mobile hunter-gatherers are similar to those of sedentary people. For sedentary groups, if raw material is available within a short distance of the residence, or if it can be regularly imported, then there is likewise no spatial or temporal difference between the location of raw material and the location of most tasks requiring the use of stone tools: both are at the residence. Consequently, there is no need for stone tools to be formally shaped since the primary factor requiring that tools be shaped – the potential to overcome future (and possibly unforeseen) raw material limitation – is no longer important. The effort which previously was invested in the manufacture of formal tools can be spent in some other task.
That raw material abundance blurs archaeologists’ ability to differentiate the technologies of mobile and sedentary populations based on common analytical approaches may explain the anomaly between the environmental conditions of the arid zone and the simple or expedient lithic technology of that region. But while this observation is important, it provides little methodological insight on how to use technological organization and the curation concept to link informal technologies back to the organization of past adaptive systems within a landscape context. People still had to meet their technological needs across a landscape, raw material abundance or not. As noted in Chapter Two, while a region may be material rich, it does not mean that people could always rely on having the material available or the time for artefact production when and where the need may have arisen. For this reason, high mobility is still likely to require some use of portable lithic technology and this should leave traces that are recognizable archaeologically. The predicament faced by researchers hoping to make the connection between morphologically simple lithic assemblages and past adaptive systems is reminiscent of the analogy Binford (1980:4-5) made when describing the task of all archaeological inference:

Thus, in order to carry out the task of the archaeologist, we must have a sophisticated knowledge and understanding of the dynamics of cultural adaptations, for it is from such dynamics that the artefacts which we observe arise. One cannot easily obtain such knowledge and understanding from the study of the archaeological remains themselves. The situation is similar to conditions during the early years of the development of medical science. We wish to be able to cure and prevent disease. Do we obtain such knowledge through the comparative study of the symptoms of disease? The symptoms are
the products of disease. Can they tell us about the causes of disease? In a like manner the archaeological record is the product or derivative of a cultural system such that it is symptomatic of the past. We cannot hope to understand the causes of these remains through a formal comparative study of the remains themselves. We must seek a deeper understanding.

In the case of lithic technology, a relative abundance of stone raw material serves to suppress the expression of the ‘symptoms’ most often associated with artefact curation in some contexts. The process of curation itself, however, likely remains even where we currently have limited or no evidence of its existence. Following Binford’s analogy, the task to be undertaken when one diagnostic test fails is to develop another.

5.6 Conclusion

This chapter outlined the interpretive potential of time-averaged assemblages both in general and as they relate to the western NSW study assemblages. Their application to the WNSWAP study assemblages results in a dynamic perspective of Aboriginal place-use throughout the mid to late Holocene. The principles behind the study of lithic technological organization provide a research perspective capable of inferring similar dynamism with the abundant flake stone assemblages of the region. Discussion of the concepts, curation and technological expedience, outlined a means through which flaked stone artefacts could be studied to understand the relationship between settlement organization and land use. While these concepts have considerable interpretive utility, current applications are susceptible to differences in
the availability of stone raw material. While it is an important observation to note that access to abundant stone raw materials complicates the relationship between the use of formalized lithic technologies and increased mobility, the need for establishing links between informal lithic assemblages and the organization of past adaptive systems remains.

The chapter that follows presents the development of an alternative perspective capable of demonstrating the effects of artefact curation within lithic assemblages dominated by unretouched flakes and cores applied to the Australian record. Extending observations about artefact curation in these assemblages to an understanding of landscape level behavioural organization is presented in the concluding chapters of this thesis.
Chapter Six

Quantification of Cortical Surface Area as a Curation Proxy
6.1 Introduction

The previous chapter outlined how the study of technological organization can help to move studies of lithic assemblage variability towards a greater understanding of the organization of past behavioural systems. Of particular interest are the concepts of curation and expedience and their potential for linking stone artefacts to past systems of land use. While these concepts are of great utility, their successful application presents challenges in many research contexts. Retouch intensity is the predominant means through which researchers currently investigate the curation process. Retouch intensity, however, is affected by raw material availability, and many assemblages lack substantial amounts of edge maintenance. Curation potentially exists in the absence of retouch, but it will go unrealized without the development of alternative proxy measures of the process. This chapter explores the development of one such proxy based around the quantification of cortex in lithic assemblages.

6.2 An Alternative Proxy Measure of the Curation Process

To explore the question of artefact curation in the absence of retouch more deeply, the largely unretouched, and therefore presumably expedient lithic technology of western NSW had to be approached in a different way. If the curation process reflects the effort to preserve artefacts in anticipation of future needs, then it is possible to define different traces of its execution. In lithic reduction, stone cobbles are broken, flakes produced, and everything eventually enters the archaeological record. The relationship between production and discard, however, is not always straight forward.
While the availability of lithic raw material may be fairly localized, the use of that material within a system of land use is not. As a result of individual and group mobility, some forms will be carried away from their place of production. This reflects how people ensured the availability of a ready supply of useable edge as they moved about the landscape, which in turn influences how and where material came to rest in archaeological context.

The effect of mobility on technological organization and assemblage structure was a central concern in Binford’s (1973) original elaboration of the curation concept. For Binford, curation meant that some artefacts were transported between sites for use in future activities and that the selection of these artefacts was dependent on their potential for future use. Because artefacts were moved from place to place, those artefacts that were most “curated” were also those likely to be under-represented at locations where they were made. As a result, these forms might be less common at the high density places that archaeologists normally identify as sites and over-represented in the ephemeral record that exists between these densities.

The intersection of curation and mobility creates an imbalance in the spatial distribution of archaeological contents; over time, assemblage composition at some points on the landscape will reflect a greater tendency for removal of the artefacts that were once there, while artefact composition at other locations will be overrepresented by artefacts produced elsewhere. This imbalance is a spatial phenomenon; while perturbations in the relationship between production and discard will persist at different scales, the effects of artefact movement will eventually cancel out as the scale of observation is extended outward to a point where the net directional
movement of stone is effectively zero. Identifying and observing this patterning has the potential to offer valuable insights into the relationship between prehistoric land use and technological organization.

The effects of artefact transport can be inferred by the presence of refurbishment debris or more rarely through refitting (e.g. Close 2000; Singer 1984). Artefact movement may also be indicated by sourcing studies, but here studies are largely limited to those sources with a readily identifiable chemical signature (e.g. Amick 1996; papers in Monet-White and Holen 1991). While these studies provide insights into the degree of individual artefact movement, it is likely that artefacts not subject to maintenance (at least by retouch) and not suitable for sourcing were also removed from some locations and transported to others. Furthermore, while refitting and sourcing studies are important measures in their own right, because a large proportion of the artefacts within assemblages are never refit and sourcing is most applicable to non-local materials, results from the application of these methods remain anecdotal at the assemblage level. The presence of individual refits or the identification of artefacts of a demonstrably non-local origin can provide an absolute measurement of the linear movement of individual forms, but they do not provide an absolute measure of the magnitude by which the process of curation has influenced the whole of assemblage composition.

Imbalances in assemblage composition (i.e. a net over or under supply of the products of lithic reduction) that are created through the selection and transport of artefacts across the landscape exist at the assemblage level and emerge whether artefacts have experienced retouch refurbishment or not. If techniques can be developed to measure
this effect, then it is possible to monitor the outcome of curation where it is less conspicuous, and importantly at a more inclusive level of analysis than currently exists in most studies. The challenge is to identify an appropriate methodology.

To address the possibility of an alternative perspective onto curation, I adopted a method developed by Dibble et al. (2005) to quantify cortical surface area in lithic assemblages. Where cortex is present on naturally occurring cobbles (as is the case within the WNSWAP study areas), the amount of cortical surface area on cobbles together with their size provides the basis for determining if all the products of core reduction are present at a particular location or if some have been removed. Equally, it is possible to suggest if products of reduction were imported to a particular location from elsewhere. Because the technique can be applied to flakes and cores that lack retouch, the method, if verified, can serve as a proxy measure for describing the effects of the curation process at the assemblage level, one that importantly can be applied in contexts where traditional measures based on the intensity of edge refurbishment are not applicable.

6.2.1 Background to the Methodology

Cortex can be useful for distinguishing between different types of raw material (e.g. Kuhn 1995; Shiner 2004), but its presence is most often used to evaluate the intensity of core reduction (e.g. Dibble et al. 1995; Holdaway et al. 2004; Shiner 2006). Theoretically there is a direct relationship between the amount of cortex retained on cores and the degree to which they have been reduced and this relationship may be used to draw inferences about the intensity with which stone was worked at particular
locations. However, there is some ambiguity in how cortex is measured and how the results of its measurement should be interpreted (Dibble et al. 2005). To overcome this ambiguity, Dibble et al. (2005) proposed a more objective approach to cortex measurement and interpretation. Using experimentally replicated assemblages and the principles of solid geometry, they demonstrated that the relationship between surface area and volume for stone cobbles could provide a means with which to gauge the over or under supply of the products of reduction.

The relationship between surface area and volume for individual nodules of stone is not constant, but instead varies by both size and shape. Because surface area increases as a cube while volume increases as a square, smaller nodules of stone have proportionally more surface area than larger ones. Similarly, the compactness or sphericity of a nodule (Wadell 1935) affects surface area to volume ratios (e.g. a sphere has proportionally less area to volume than a cube). This effect means that each individual reduced nodule possessed its own unique surface area to volume ratio. While this complicates the interpretation of cortex proportions, Dibble et al. (2005) demonstrated that when combined, the different surface area to volume ratios of separate nodules can be accurately expressed with reference to their average size and approximate three dimensional shape (e.g. a sphere, cube, or cone). When this average is known, the total volume represented by the artefacts in an assemblage can be used to calculate the total cortical surface area that should be present within an assemblage and this value can then be compared to the actual quantity that is measured on the artefacts themselves. The relationship between observed and expected quantities of cortical surface area is expressed as the Cortex Ratio. If all products of cobble reduction are present, the Cortex Ratio will approximate one. If
products have been transported to or from an assemblage, the Cortex Ratio will be either higher or lower than one accordingly.

Dibble et al. (2005) demonstrated a “proof of concept” but they advocated further study to replicate their findings and to establish the utility of the method for assemblages with different raw materials and from archaeological rather than solely experimental contexts. The following presents a further test and archaeological application of their methodology, and then explores its utility as an alternate means of assessing the effects of stone artefact curation.

6.2.2 Adaptation of the Cortex Method

The variables and values recorded for the NSW assemblages differ somewhat from those used by Dibble et al. in their study. Nevertheless, the data recorded are sufficiently similar for the solid geometry method to be applied. The variables of relevance are Observed Cortical Surface Area, Assemblage Mass and Average Nodule Volume.

The observed cortical surface area of each artefact was obtained using maximum clast dimensions to ensure consistency between different artefact classes. Maximum length represents the distance between the two points farthest apart from each other irrespective of orientation. Maximum width is taken at the widest point perpendicular to the length axis, and maximum thickness is recorded at the thickest point along the third dimension (Holdaway and Stern 2004:138-140). Flake, flake fragment, and angular fragment surface areas were obtained by multiplying length by width, while
core surface area was established by entering the length, width and thickness semi-axes into an equation for the surface area of an ellipsoid (Figure 6.1):

$$S = 4\pi[(a^p b^p + a^p c^p + b^p c^p)/3]^{1/p}$$

where $p$ is 1.6075 and $a$, $b$, and $c$ are the semi-axes of length, width, and thickness (Thomsen 2004).
Fig 6.1: Scalene Ellipsoids. The choice of this geometric solid for the estimation of surface area was made for two reasons. (1) It provides a reasonable approximation of the rounded nature of the majority of the Australian cores, and (2) it enables the use of all three core dimensions contained in the WNSWAP data (as opposed to the other geometric solids (e.g. sphere, oblate and prolate spheroids)).
Surface area values were then multiplied by the midpoint of the percentage of cortex recorded for each artefact. Dibble and colleagues recorded cortex percentage using a seven interval scale (2005: 548-49). The WNSWAP data were recorded at four intervals (0, 1-49, 50-99, 100) to reduce inter observer error (Gnaden and Holdaway 2000). The cortical surface areas for all artefacts in an assemblage were summed to arrive at the total observed cortical surface area.

Artefact mass was not recorded for all the assemblages reported due to the logistic difficulties of operating scales in the field (artefacts were returned to the place where they were found, a condition required by Aboriginal custodians). However, with the availability of economical battery operated digital scales the measurement of artefact mass was incorporated into the most recent field work of WNSWAP. Data obtained during the 2006 field season served as the basis for a linear regression to predict artefact mass for the silcrete components of the assemblages analyzed here. For quartz artefacts, a second regression set was produced from experimentally replicated specimens housed within collections at The University of Auckland.

Dimensional volume (length x width x thickness) was found to correlate strongly with artefact mass for both quartz and silcrete. For quartz, separate regressions for those artefacts with volumes greater than 35 cm$^3$ and those below 35 cm$^3$ yielded the best results (> 35 cm$^3$: $r^2 = .947$, standard error = 2.209, $p < .001$; < 35 cm$^3$: $r^2 = .969$, standard error = 18.254, $p < .001$). This probably reflects improved agreement between measured and actual volume for the larger, blockier quartz artefacts. For silcrete, separate regressions for different classes of artefacts generated the best fit (angular fragment: $r^2 = .967$, standard error = 2.938, $p < .001$; flake fragment: $r^2 =$
.959, standard error = 2.424, \( p < .001 \); complete flake: \( r^2 = .961 \), standard error = 3.314, \( p < .001 \); core: \( r^2 = .982 \), standard error = 63.131, \( p < .001 \); proximal fragment: \( r^2 = .964 \), standard error = 1.849, \( p < .001 \).

The resulting models are:

Silcrete Mass

\[
\text{Angular Fragment} = (.919) \times \text{dimensional volume} \\
\text{Flake Fragment} = (.890) \times \text{dimensional volume} \\
\text{Complete Flake} = (.886) \times \text{dimensional volume} \\
\text{Core} = (1.008) \times \text{dimensional volume} \\
\text{Proximal Fragment} = (.859) \times \text{dimensional volume}
\]

Quartz Mass

\[
\text{Artefacts less than } 35 \text{ cm}^3 = (.909) \times \text{dimensional volume} \\
\text{Artefacts over } 35 \text{ cm}^3 = (1.008) \times \text{dimensional volume}
\]

Following Bradbury and Carr (1999), a further assessment of the performance of each model was completed by regressing actual mass on predicted mass to determine the slope of the model (i.e. actual mass = (regression coefficient x predicted mass)). Deviation from a value of one suggests that the model will either over- or under-estimates actual values.

For both silcrete and quartz, the relationship between mass and predicted mass yielded a slope of 1.00 indicating that there is no systematic bias introduced when using the models. The resulting predicted mass values were then used to establish
artefact volume through division by material density (2.53 for silcrete and 2.64 for quartz, as determined by the Berman method [1939]).

The volume of the nodules Aboriginal people selected in the past is unknown so it was decided to adopt the suggestion of Dibble et al. (2005) and use the number of cores in an assemblage as a proxy for the number of nodules reduced. In doing this, flake and bipolar cores were excluded as their presence would have unduly inflated expected cortex values\(^1\). Based on this suggestion, theoretical nodule volume equals assemblage volume divided by core frequency.

Expected assemblage cortical surface area was obtained following the method Dibble et al employed in their experiments. The average nodule volume (\(V\)) for each assemblage was input into the equation for the surface area of a sphere:

\[
S = 4\pi \left(\frac{3V}{4\pi}\right)^{2/3}
\]

Average nodule surface area was then multiplied by the number of nodules represented in the assemblage (the same value as the number of cores used to determine the estimate of nodule size) to arrive at the total expected cortical surface area.

Division of observed cortical surface area by the expected cortical surface area provides the Cortex Ratio. Values of this ratio near one indicate a close match between observed and expected cortical surface area, while values under one indicate that cortex is underrepresented and values over one indicate that cortex is overrepresented.
6.2.3 Testing the model

Before the solid geometry method (modified for Australian recording protocols) could be applied to archaeological assemblages, it was important to test its accuracy against materials in which Cortex Ratios are already known. To do this I analyzed experimentally replicated artefacts made from raw material obtained from some of the NSW study areas.

Seven cortical silcrete cobbles collected in the vicinity of Peery Lake, and six cortical quartz cobbles collected in the Fowlers Gap study area were reduced to varying degrees by direct free-hand percussion with quartzite hammerstones. The silcrete cobbles were reduced by me, while the quartz cobbles were reduced by Dan Witter and Justin Shiner. Reduction followed a general Australian model (Flenniken and White 1985) and the experimental sets produced resembled those encountered in the western NSW study locations. All materials equal to or greater than two cm in maximum dimension were recorded for the relevant variables and then analyzed following the methods outlined above.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass (gm)</th>
<th>Predicted Mass (gm)</th>
<th>N</th>
<th>Observed Cortex (cm²)</th>
<th>Expected Cortex (cm²)</th>
<th>Cortex Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silcrete</td>
<td>3772.7</td>
<td>3945.8</td>
<td>7</td>
<td>1288.7</td>
<td>1244.1</td>
<td>1.03</td>
</tr>
<tr>
<td>Quartz</td>
<td>1447.3</td>
<td>1441.5</td>
<td>6</td>
<td>604.8</td>
<td>587.1</td>
<td>1.03</td>
</tr>
</tbody>
</table>

The results from the experimental sets (Table 6.1) indicate that the methodology described above predicts actual conditions quite well. Total assemblage mass as determined with the regression formulae are accurate within five percent of actual
values and Cortex Ratios are within five percent of one. These results indicate that the solid geometry method, using the modified operations, can be appropriately applied to archaeological assemblages. With this confirmed the method, was applied to the WNSWAP study assemblages.

6.3 Results

The cortex methodology was initially applied to two samples of the WNSWAP study data; 32,000 data records (Douglass et al. 2008) and 20,000 additional data records (Holdaway et al. 2008c), and has now been applied to all WNSWAP data records recorded up to 2005, reflecting a combined total of 123,394 artefacts.

Table 6.2 shows the ratios obtained between observed and expected cortical surface area (i.e. the Cortex Ratio) for all the western NSW study locations. All the results are consistently below one indicating that cortex is under-represented among these assemblages and therefore that artefact transport was a factor influencing assemblage formation.
### Table 6.2: WNSWAP Assemblage Cortex Ratios (L) = local (N) = non-local.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BC</td>
<td>Quartz (L)</td>
<td>1934</td>
<td>115</td>
<td>9465</td>
<td>3687</td>
<td>5509</td>
<td>0.67</td>
</tr>
<tr>
<td>BC</td>
<td>Silcrete (N)</td>
<td>4302</td>
<td>121</td>
<td>18029</td>
<td>1383</td>
<td>8858</td>
<td>0.16</td>
</tr>
<tr>
<td>CN1</td>
<td>Quartz (L)</td>
<td>7270</td>
<td>495</td>
<td>90250</td>
<td>26567</td>
<td>40295</td>
<td>0.66</td>
</tr>
<tr>
<td>CN1</td>
<td>Silcrete (N)</td>
<td>1427</td>
<td>41</td>
<td>16851</td>
<td>1342</td>
<td>5903</td>
<td>0.23</td>
</tr>
<tr>
<td>CN3</td>
<td>Quartz (L)</td>
<td>4139</td>
<td>286</td>
<td>52495</td>
<td>16075</td>
<td>23386</td>
<td>0.69</td>
</tr>
<tr>
<td>CN3</td>
<td>Silcrete (N)</td>
<td>689</td>
<td>26</td>
<td>7607</td>
<td>493</td>
<td>2984</td>
<td>0.17</td>
</tr>
<tr>
<td>CW</td>
<td>Silcrete (L)</td>
<td>5016</td>
<td>250</td>
<td>67971</td>
<td>15208</td>
<td>27327</td>
<td>0.56</td>
</tr>
<tr>
<td>FC</td>
<td>Quartz (L)</td>
<td>4596</td>
<td>411</td>
<td>62119</td>
<td>18477</td>
<td>29524</td>
<td>0.63</td>
</tr>
<tr>
<td>FC</td>
<td>Silcrete (N)</td>
<td>267</td>
<td>9</td>
<td>2504</td>
<td>351</td>
<td>999</td>
<td>0.35</td>
</tr>
<tr>
<td>FW</td>
<td>Quartz (L)</td>
<td>1453</td>
<td>98</td>
<td>15483</td>
<td>3605</td>
<td>7251</td>
<td>0.50</td>
</tr>
<tr>
<td>FW</td>
<td>Silcrete (N)</td>
<td>228</td>
<td>10</td>
<td>1637</td>
<td>205</td>
<td>780</td>
<td>0.26</td>
</tr>
<tr>
<td>KZ1</td>
<td>Quartz (L)</td>
<td>2173</td>
<td>137</td>
<td>24217</td>
<td>5535</td>
<td>10924</td>
<td>0.51</td>
</tr>
<tr>
<td>KZ1</td>
<td>Silcrete (N)</td>
<td>1179</td>
<td>43</td>
<td>15077</td>
<td>732</td>
<td>5569</td>
<td>0.13</td>
</tr>
<tr>
<td>KZ2</td>
<td>Quartz (L)</td>
<td>6956</td>
<td>396</td>
<td>61731</td>
<td>16876</td>
<td>29039</td>
<td>0.58</td>
</tr>
<tr>
<td>KZ2</td>
<td>Silcrete (N)</td>
<td>4073</td>
<td>127</td>
<td>39866</td>
<td>3284</td>
<td>15278</td>
<td>0.21</td>
</tr>
<tr>
<td>MD</td>
<td>Quartz (L)</td>
<td>2702</td>
<td>198</td>
<td>25675</td>
<td>8582</td>
<td>12842</td>
<td>0.67</td>
</tr>
<tr>
<td>MD</td>
<td>Silcrete (N)</td>
<td>1351</td>
<td>39</td>
<td>10220</td>
<td>1072</td>
<td>4160</td>
<td>0.26</td>
</tr>
<tr>
<td>ND</td>
<td>Quartz (L)</td>
<td>2941</td>
<td>265</td>
<td>20949</td>
<td>8461</td>
<td>12358</td>
<td>0.68</td>
</tr>
<tr>
<td>ND</td>
<td>Silcrete (L)</td>
<td>2127</td>
<td>87</td>
<td>19627</td>
<td>3105</td>
<td>8397</td>
<td>0.37</td>
</tr>
<tr>
<td>NN</td>
<td>Quartz (L)</td>
<td>1320</td>
<td>169</td>
<td>21315</td>
<td>4220</td>
<td>10760</td>
<td>0.39</td>
</tr>
<tr>
<td>NN</td>
<td>Silcrete (N)</td>
<td>286</td>
<td>7</td>
<td>2388</td>
<td>205</td>
<td>890</td>
<td>0.23</td>
</tr>
<tr>
<td>NP</td>
<td>Silcrete (L)</td>
<td>1299</td>
<td>62</td>
<td>14856</td>
<td>2373</td>
<td>6230</td>
<td>0.38</td>
</tr>
<tr>
<td>RH</td>
<td>Silcrete (L)</td>
<td>3006</td>
<td>232</td>
<td>106214</td>
<td>18152</td>
<td>35894</td>
<td>0.51</td>
</tr>
<tr>
<td>SC</td>
<td>Quartz (L)</td>
<td>3222</td>
<td>287</td>
<td>31228</td>
<td>11084</td>
<td>16560</td>
<td>0.67</td>
</tr>
<tr>
<td>SC</td>
<td>Silcrete (N)</td>
<td>1443</td>
<td>49</td>
<td>28973</td>
<td>3644</td>
<td>8991</td>
<td>0.41</td>
</tr>
<tr>
<td>SQ</td>
<td>Silcrete (L)</td>
<td>4151</td>
<td>97</td>
<td>84347</td>
<td>13124</td>
<td>23017</td>
<td>0.57</td>
</tr>
<tr>
<td>ST</td>
<td>Quartz (L)</td>
<td>1541</td>
<td>127</td>
<td>17040</td>
<td>5850</td>
<td>8426</td>
<td>0.69</td>
</tr>
<tr>
<td>ST</td>
<td>Silcrete (N)</td>
<td>96</td>
<td>1</td>
<td>514</td>
<td>83</td>
<td>167</td>
<td>0.50</td>
</tr>
<tr>
<td>Stud1</td>
<td>Silcrete (L)</td>
<td>20066</td>
<td>1257</td>
<td>235195</td>
<td>56073</td>
<td>109191</td>
<td>0.51</td>
</tr>
<tr>
<td>Stud2</td>
<td>Silcrete (L)</td>
<td>24202</td>
<td>1013</td>
<td>263429</td>
<td>50522</td>
<td>107493</td>
<td>0.47</td>
</tr>
<tr>
<td>Stud3</td>
<td>Silcrete (L)</td>
<td>7939</td>
<td>733</td>
<td>132912</td>
<td>31577</td>
<td>61162</td>
<td>0.52</td>
</tr>
</tbody>
</table>
The magnitude of the discrepancy between observed and expected cortical surface area values varies by material type (Table 6.2): in every case, quartz values are higher than those of silcrete, indicating that the quartz assemblages more nearly approximate the values expected if all products of reduction were present. There are several potential explanations for this result.

The mechanical properties of quartz are such that it is prone to flaws, explaining a reputation in Australia and elsewhere for it being difficult to work (Holdaway and Stern 2004:116-118). The analysis presented here supports this position, as all the quartz assemblages contain an abundance of angular fragments and these fragments retain a large portion of the total cortical surface area in each case (Table 6.3). While angular fragments were occasionally used (as evidenced by retouch), in the majority of cases they probably represent waste and were therefore unlikely to have been transported.

Table 6.3: Cortex Values by Artefact Class (both Mean Cortex Percentage (Cortex %) and Proportion of Total Cortical Surface Area (%CSA) For the Sample of Assemblages With Both Silcrete and Quartz Presented in Douglass et al. (2008).  

<table>
<thead>
<tr>
<th>Assemblage</th>
<th>Artefact Class</th>
<th>Silcrete Cortex %</th>
<th>Silcrete % CSA</th>
<th>Quartz Cortex %</th>
<th>Quartz% CSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC</td>
<td>Angular Fragment</td>
<td>0.04</td>
<td>0.04</td>
<td>0.30</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>Flake and Flake Fragment</td>
<td>0.04</td>
<td>0.66</td>
<td>0.27</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>Core</td>
<td>0.09</td>
<td>0.30</td>
<td>0.34</td>
<td>0.36</td>
</tr>
<tr>
<td>CN1</td>
<td>Angular Fragment</td>
<td>0.04</td>
<td>0.01</td>
<td>0.25</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>Flake and Flake Fragment</td>
<td>0.04</td>
<td>0.48</td>
<td>0.23</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>Core</td>
<td>0.14</td>
<td>0.51</td>
<td>0.42</td>
<td>0.53</td>
</tr>
<tr>
<td>ND</td>
<td>Angular Fragment</td>
<td>0.12</td>
<td>0.09</td>
<td>0.30</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>Flake and Flake Fragment</td>
<td>0.1</td>
<td>0.52</td>
<td>0.29</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>Core</td>
<td>0.21</td>
<td>0.39</td>
<td>0.44</td>
<td>0.43</td>
</tr>
</tbody>
</table>
As well, quartz cores retain a disproportionately high proportion of cortex compared to those manufactured from silcrete. For assemblages with both quartz and silcrete components, quartz cores are not only more cortical than silcrete cores, they also retain a greater percentage of the total cortical surface area than that contributed by the flake component (Table 6.3). This may in part be related to size differences between quartz and silcrete cobbles since silcrete cobbles are generally larger than their quartz counterparts. As a cobble is reduced, it becomes smaller and the flakes that are produced from it become smaller as well, up to the point where the reduced core is discarded as waste (e.g. Dibble et al. 1995; Holdaway et al. 2004; Roth and Dibble 1998). Perhaps because of the smaller size of unworked quartz cobbles, quartz cores were discarded with fewer flake removals than silcrete cores, thus leaving a waste product with relatively greater quantities of cortex.

A third explanation for the different results obtained for quartz and silcrete relates to the location of these raw materials relative to our study locations. In each of the examples where quartz was reduced, this material is available within the immediate vicinity of the sampling area. Silcrete, on the other hand, is more variable, sometimes being located away from the sampling areas and sometimes being available locally (Table 6.2). As Table 6.2 shows, components of assemblages represented by non-local materials display a greater discrepancy between observed and expected cortical surface area than those components manufactured from locally available raw materials. Differences between silcrete and quartz are still apparent, but their magnitude is diminished. Raw material that can be readily obtained in the immediate environment obviously has lower procurement costs and is therefore likely to be utilized less intensively given similar occupation histories (Elston 1990).
As a cobb is reduced its mass becomes distributed amongst the various products of reduction. While artefact transport will affect this relationship, a measure of core mass relative to total assemblage mass provides an indication of how intensively cobbles were reduced before abandonment.

Table 6.4 gives the ratio of core mass to total assemblage mass for a sample of the WNSWAP assemblages presented in Douglass et al. (2008). These values suggest that cores made from locally available raw materials are generally less intensively reduced when compared to those produced from non-local material.

SQ1 and ND deviate slightly from this pattern, where locally available silcrete was reduced with an intensity comparable to that of non-local materials in other assemblages. However, within the greater study areas that these two locations are found, silcrete is fairly uncommon. The intensity of reduction at these two assemblages, therefore likely reflects a desire on the part of prehistoric knappers to take advantage of what is still an uncommon resource. These results support a correlation between the intensity of raw material utilization and the Cortex Ratios suggesting that differences in material availability play a role in decisions about artefact transport.

Table 6.4: Index of Core Reduction Intensity (Core Mass/ Total Assemblage Mass). This Value Approximates the Percentage of Nodule Mass Retained on the Cores.

<table>
<thead>
<tr>
<th>Assemblage</th>
<th>Silcrete %</th>
<th>Quartz %</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC</td>
<td>Non-Local</td>
<td>17.7</td>
</tr>
<tr>
<td>CN1</td>
<td>Non-Local</td>
<td>29.4</td>
</tr>
<tr>
<td>CW</td>
<td>Local</td>
<td>35</td>
</tr>
<tr>
<td>ND</td>
<td>Local</td>
<td>28.4</td>
</tr>
<tr>
<td>RH</td>
<td>Local</td>
<td>40.5</td>
</tr>
<tr>
<td>SQ1</td>
<td>Local</td>
<td>28.1</td>
</tr>
</tbody>
</table>
In summary, the Cortex Ratios for over 123,000 artefacts distributed across a large portion of western NSW suggests a regional pattern of the under-representation of cortex from lithic assemblages marked by local production. Observed cortical surface area is consistently below expected values, indicating the importance of artefact transport both in the organization of technology and assemblage formation. This degree of movement is in contrast to the assumed nature of lithic technology in the greater region where it is presumed that the morphological simplicity of the flakes and cores that dominate assemblage contents reflect artefacts that have been produced used and discarded all in one place (see Chapter Two). Material availability played a role in the degree to which cortex is underrepresented in this study but there is evidence that artefacts manufactured from both imported and locally available materials were transported, hence this factor alone does not explain the results obtained.

6.4 Discussion

The underrepresentation of cortical surface area within these assemblages could occur in one of two ways. Either a large quantity of stone where cortex was largely absent was brought in (i.e. the importation of non-cortical flakes and cores), or artefacts that were disproportionately cortical were removed for use elsewhere. As noted in Chapter Two, the greater WNSWAP study region falls within the Australian stony desert and as such has a ready abundance of raw material sources in the form of cobble lined creek beds, gibber pavements and outcroppings with associated boulder mantles. All of the study assemblages (e.g. Figure 6.2) have knappable stone of one form or another within their immediate vicinity. RH and SQ1 for example are situated directly upon
sources of high quality silcrete. Visual inspection of the artefacts within these assemblages indicates that it is this local stone that dominates assemblages numerically. It is therefore highly improbable that the consistent underrepresentation of cortical surface area in each of the WNSWAP assemblages is owed to the addition of large quantities of indistinguishable stone from one source to another (i.e. the importation of decortified cobbles and non-cortical flakes). Instead, the underrepresentation of cortical surface area is most likely the result of the selective removal of material from the place of their production for use and eventual discard elsewhere. What remains in these assemblages are the products of reduction not selected for transport but instead left behind as refuse. Many but not necessarily all of these desirable products retained some cortex.
Figure 6.2 Typical Relationship between WNSWAP Assemblage Location and Stone Raw Material Availability. Sources of stone raw material are found in cobble lined creek beds, extensive gibber pavements and as outcroppings. Each of the WNSWAP study assemblages is positioned adjacent to or directly upon a source of knappable stone. This local stone is the dominant raw material found in most assemblages (the exception being BC).
The decision to abandon something or to retain it was likely based on some consideration of utility (\textit{sensu} Shott 1996). People carried stone to supply themselves with usable edges in anticipation of the possibility of future needs (Kuhn 1995; Nelson 1991), in all likelihood selecting artefacts that provided a greater efficiency in use and/or possessed the potential for extended use-life (Kuhn 1994, 1996; Roth and Dibble 1998). Once reduced, the individual products of reduction each possess their own relationship between cortical surface area and volume, but combined, they retain the original ratio of the unworked cobbles. It is the variable selection of the products of reduction that affects Cortex Ratios rather than selection of flakes with cortex. The Cortex Ratio of the materials left behind will be less than one when artefacts are removed that on average have more cortical area to volume than existed on the original cobbles.

In the reduction of cortical cobbles there are two sure trends. Cortex is removed and the core gets smaller, meaning the quantity of cortex on flake products decreases and the size of the flakes produced tends to decrease as the core becomes more reduced. The result is that larger flakes are disproportionately represented by early removals within the reduction process and are therefore likely to retain more cortex while later reduction is disproportionately represented by smaller non-cortical flakes (e.g. Baumler 1988; Dibble \textit{et al.} 1995).

Australian Ethnographic accounts (e.g. Binford and O’Connell 1984:428; Hayden 1979:26; Tindale 1965:140) of reduction routinely discuss knappers reducing cores – often quite extensively – and then looking over flake products to select those taken for use elsewhere. A tendency towards the preferential removal of larger, and therefore
disproportionally cortical, flakes from the products of reduction would create the pattern of the under-representation of cortex in the NSW assemblages. Studies conducted elsewhere show that imported lithic artefacts tend to be relatively large (e.g. Dibble 1997; Rolland 1981; Roth and Dibble 1998) as do those forms that have received extended use (e.g. Dibble 1988, 1997; Dibble and Holdaway 1993; Dibble et al. 1995; Keeley 1980:154-5; Roth and Dibble 1998).

Interpreting the pattern of underrepresented cortex for non-local components of these assemblages is less straightforward because of the unknown state in which lithic material was brought to a location: materials could have been imported in the form of fully cortical cobbles, partially worked cores, or retouched and unretouched blanks, or more likely some combination of the three. Webb (1993), who studied assemblages from Kinchega National Park, a location not far from the Burkes Cave assemblage (Chapter Four), documented the movement of fully cortical cobbles as well as worked cores within an area devoid of naturally occurring lithic materials. This indicates that within the western NSW study region, fully cortical cobbles were at times imported to places where stone was locally unavailable. There is, however, no evidence to suggest that this was the only or even the predominant strategy by which non-local material was transported. It seems quite probable that some cobbles would have found their way to the NSW study locations after having been utilized elsewhere. Such material may have lacked cortex, its removal having occurred at other locations before final abandonment. Such a process would therefore have the effect of depressing Cortex Ratios. On the other hand, the consistent pattern amongst material available locally suggests the preferential selection of large flakes for transport elsewhere. Raw
material importation following this strategy would have the opposite effect of inflating cortex proportions.

The NSW archaeological assemblages have high artefact densities and chronologies consistent with repeated use over time. Depending on surface visibility in the past (admittedly not easy to gauge because of erosion over the last 150 years discussed in Chapter Three) previous artefact discard may have formed a raw material source similar in potential to naturally occurring deposits. The pattern amongst local components of these assemblages suggests a process of artefact removal. While the effect of importation on Cortex Ratios is unknown, it is doubtful that non-local material was treated in a manner that was fundamentally different from those obtained locally meaning imported materials were at times scoured for high utility flakes. If quantities of imported raw material, like their local counterparts, simply served as potential sources of useable stone, assemblage composition would reflect the operation of decisions about relative artefact utility, and therefore suitability for transportation, iterated through time. Such processes would serve to deplete concentrations of flaked stone of cortical surface area and likely contributed much to the patterning noted amongst the non-local materials in the NSW assemblages. Material availability played a role but there is evidence that artefacts manufactured from both imported and locally available materials were transported, hence this factor alone does not explain the results obtained.

If material was leaving, then where was it going? At present it is difficult to answer this question directly, but it is possible to propose a number of likely scenarios. Dibble *et al.* (1995:265-6) and Roth and Dibble (1998) suggest that upon leaving a
location, occupants would likely gather up lithic material (tools, blanks, cores, and even unworked nodules) to carry with them to their next destination. Whether these materials were manufactured from local or imported materials would not have weighed highly in transport decisions. Instead selection would reflect differences in artefact quality and size. This simple process of individuals availing themselves of material at the end of an occupation, iterated through time, could result in the movement of considerable quantities of stone. Any bias in selection would therefore significantly affect the resulting Cortex Ratios of the materials that were not selected.

Close (2000) provides an alternative scenario in her study involving the transport of artefacts over distances ranging from a few meters to a couple of kilometres. Her study of refit sequences among Neolithic assemblages manufactured from imported materials in the southwest of Egypt showed how materials were repeatedly moved throughout a 15 square kilometre study area. While she did recognize traces indicating more extended transport, the majority of her inter-site refits reflected a pattern where people would have transported stone short distances from one resource patch to the other. Through time, people carrying stone for short distances from where it was obtained to where it was used would result in the movement of large quantities of material. Such a process could have a significant effect on cortex proportions.

Because of the time-averaged nature of these assemblages, it is likely that both processes of artefact removal played a role in the formation of the pattern of underrepresented cortex. As well, there is no doubt that other explanations could be developed. All of the WNSWAP study locations represent high density artefact concentrations with associated hearth clusters, but they represent only a small portion
of the entire utilized landscape. Because cortex is consistently underrepresented along these nodes of increased density, it is therefore likely that the missing cortex exists in the form of low density scatters and isolates strewn about the greater landscape. The large forms removed from locations marked by flake production must eventually find their way into the archaeological record. It is through discard away from nodes of artefact abundance (i.e. those areas most often targeted for archaeological study) that an imbalance between artefact production and discard has emerged. By extending the scale of observation outward from areas where cortical surface area is underrepresented, unity between the quantity of cortex observed and the quantity of cortex that is expected will eventually be restored. Discovering that scale at any given location on the landscape, however, is an empirical question. It is conceivable that unity may be restored relatively quickly, but it is also conceivable that analysis at far greater spatial scales will still fail to right the imbalance in measured cortex proportions. Regardless, exploiting the scales at which imbalance persists in this measure has direct relevance for understanding the nature of land use in the past.

6.5 Conclusion

The quantification of cortical surface area indicates a repeated pattern of the underrepresentation of cortex from areas of local stone availability, thus suggesting the operation of a process of artefact removal for use in future activities. The pattern is not a measure of the removal of individual artefacts, but is instead a reflection of the impact of this process on the composition of the artefacts that were not selected and thus remain in the concentrations of archaeological material that archaeologists routinely target for study. The fact that cortical surface area is so underrepresented for
a large suite of study areas totalling over 123,000 artefacts distributed over a large
portion of western NSW suggests both that Aboriginal Australians were quite
discerning when selecting artefacts for transport and that the actual removal of
artefacts was extensive. The potential implications of the identified pattern are of
considerable importance both to the understanding of Aboriginal technological
organization as well as to the study of lithic assemblage variability in general.

If correct, the results of this study provide a vantage onto the process of curation in a
ccontext where previous interpretations of the dearth of retouch and formalized core
reduction would indicate that the record lacks investment in the organization of lithic
technology. With a large data set, sampled from assemblages of varying densities and
spatial scales, distributed across a large portion of the western NSW desert, retouch
remains strikingly low and core patterning shows little if any evidence of
predetermination. From the record that is available for this study – one that provides a
landscape perspective that is much broader than many existing studies – assemblage
variability appears to present a textbook case of technological expedience. The pattern
of missing cortex, however, suggests otherwise.

If correct, the identification of extensive curation of unretouched flakes produced
from non-formalized cores would question a link between a de-emphasis on artefact
retouch and the process of technological expedience as well as the notion that
morphological complexity equates to the complexity of intention. Simply put, the
impetus for this study was the desire to understand the anomalous situation of an
apparently casual technology within a demanding environmental context. Results
indicate that the anomaly is not that Aboriginal populations did not invest in their
lithic technology, but that their use of this technology does not conform to current understanding of the ways stone tool use ought to be structured. If true, then much of the interesting information reflected in Aboriginal stone tool use is outside the purview of conventional means for relating stone tool assemblage variability to past behavioural organization. While it is advantageous to identify areas where current theoretical understandings fail when confronted with real world realities, the challenge when making such observations is that the standard of proof is necessarily high. The best strategy for meeting this challenge is through additional testing and refinement of the cortex methodology in order to assess the validity of preliminary results. The completion of this additional study will be addressed in the following chapters.

Note: (1) While technically cores, flake and bipolar cores are not representative of the nodules from which the bulk of assemblage contents were produced. Their inclusion would thus lead to overestimates in nodule frequency and underestimates of average nodule size. As smaller nodules have greater surface area per unit volume, the effect of this scenario would be for expected quantities of cortical surface area to be overestimated.
Chapter Seven

Additional Methods
7.1 Introduction

The preceding chapter outlined the application of a methodology for the quantification of cortical surface area for use as a proxy measure of stone artefact curation. Modifications to the original methodology developed by Dibble et al. (2005) were made to accommodate the WNSWAP artefact recording protocols and then tested experimentally. The methodology was then applied to a large suite of lithic data from western NSW, Australia. The resulting pattern obtained through these efforts indicated that cortex is consistently underrepresented from all the assemblages available to study.

The magnitude by which cortical surface area is underrepresented in each assemblage, and the fact that this pattern persists in a broad sample of the assemblages suggests considerable movement of stone in the anticipation of future needs. If true, these results would indicate that rather than reflecting a casual approach to lithic technology, the patterning observed amongst abundant surface scatters is an outcome of extensive artefact curation. Not only would such a finding contradict the assumption of casualness, but the observation of the intensive selection and movement of expediently produced flakes from largely unpatterned cores would contrast markedly with conventional understanding of stone tool use. Quite simply, these results suggest that the Australians were breaking all of the ‘archaeological’ rules.

For these reasons, it is of the utmost importance that additional study be completed to further test the validity of the preliminary results. The best means by which this
additional study can proceed is through the identification of potential sources of error that could invalidate the identified pattern. With this aim, I have identified the following areas that deserve further consideration: Data Quality, Methodological Reliability and Methodological Refinement.

Data Quality: Are the measurements that are made in the field sufficiently precise for the proper measurement of cortical surface area? The determination of observed cortical surface area uses artefact dimensions and estimates of cortex proportion. While these are standard measures in lithic analysis, they remain fairly imprecise. Could this imprecision be a source of error that is creating a false result?

Methodological Reliability: Will the cortex methodology consistently provide a value near one when all products of reduction remain for study? Preliminary testing in the preceding chapter suggested that the methodology was sound, but the sample size was small. What is the likelihood that the cortex methodology will provide a false impression of artefact movement when indeed there was none? Even if artefact transport is accepted, does the pattern of missing cortex necessarily imply that there was a process of selecting specific artefacts in an effort to equip people with high utility blanks, or could it instead simply be an effect of haphazard selection?

Methodological Refinement: The cortex methodology is based on having the ability to approximate the average size and shape of the nodules of stone that were knapped to produce an assemblage. In experimental contexts these parameters are known; archaeologically they must be estimated. For instance, the means by which nodule size was determined in the preliminary analysis might be flawed. With what certainty
is it known that there was only one core for each cobble and were cores correctly identified? If flakes are transported away, assemblage mass will not reflect original mass, and will thus create a source of error in the estimate of average nodule size. Without a refined means of determining Average Nodule Size, or verifying the adequacy of existing techniques, ambiguity in results will persist.

This chapter provides the results of studies that address these issues. First additional testing is completed with a large suite of experimental data through the use of laser scanning and computer simulation. This testing is aimed at evaluating the quality of the data used in the cortex methodology as well as the potential for false results. Second, techniques for the more accurate determination of average nodule size are developed, as well as an alternative approach to investigating the question of underrepresented cortex based on a comparison of the relationship of cortical surface area and volume found in the assemblage and that same relationships as it exists on the stone obtained near each study assemblage. The results of the application of these methodologies to the WNSWAP data will be presented in Chapters Eight and Nine.

7.2 Further Evaluation of Existing Cortex Methodology

To complete additional testing of data quality and methodological reliability a much larger data set in which true cortex quantities were known was needed. This required the creation of a much expanded experimental study collection.
7.2.1 Experimental Methods

Fifty seven silcrete and 25 quartz cobbles were selected from locations within Paroo-Darling National Park, Pine Point and Langwell stations, and Fowlers Gap Arid Zone Research Station. Cobbles were selected from a variety of contexts within these areas in order to gather a range of the material variability available within the greater study region. Materials include those from cobble bars within dry creek lines, gibber pavements, and along outcroppings. A large range of cobbles sizes for both silcrete and quartz was selected. Cobbles were labelled with a unique identification and a number of attributes were recorded (e.g. mass, and clast dimensions). Quartz cobbles varied in initial size from 49 grams to 1386 grams, while Silcrete cobbles ranges from 53 to 2232 grams.

Cobbles were reduced by direct freehand percussion using a variety of hammer stones by knappers of varying skill levels. Some reductions were completed in the lab, some during field work, and finally some of the experimental data reflect refit sets housed in the comparative collections at The University of Auckland. As noted in Chapter Six, reduction followed a generalized Australian model (Flenniken and White 1985), and the materials produced resembled those observed archaeologically. The objective was to produce flakes displaying the range of variation observed archaeologically rather than the production of distinctive core types. Core varieties found in Australian assemblages were replicated in these experiments (with the exception of various flake and bipolar forms), though the reduction trajectory taken by individual cores was seldom confined to a single form within the typology.
7.2.2 Assessing Infield Data Quality

In both the original methodology developed by Dibble et al. (2005) and its modification to accommodate Australian recording protocols, the observed cortical surface area was derived from ordinal percentage approximations of visible cortex proportion on each artefact and mechanical measures of artefact dimension with callipers. While these are typical means of obtaining measurements in lithic analysis, both are nevertheless imprecise estimates of the true values and it remains uncertain what impact the precision of the measurements might have on the calculation of observed cortical surface area. To address this issue, additional study was completed in order to evaluate the impact of measurement precision on the cortex methodology using 3D laser scanning. This component of the cortex research relates to a collaborative project completed at the University of Auckland (Lin, Douglass, Holdaway and Floyd 2010). Data acquisition and analysis was completed by Sam Lin. The following is a summary of this study.

Three dimensional scanning provides a precise measure with which to evaluate the performance of the conventional techniques used in data analysis. To complete this comparison, five of the experimental reduction sets were selected for further analysis. In order to maximize variability, sets were selected so as to provide a broad range in both cobble size and core reduction intensity. In total, the sets produced from these cobbles reflected one hundred and twenty one artefacts greater than or equal to two cm in maximum dimension (i.e. five cores and 116 flakes). To increase the number of cores upon which measurements were compared, measurements for an additional 25 cores from the experimental materials were also completed. All artefacts were
measured following the recording protocols outlined in the preceding chapter and
scanning was completed with a Konica Minolta Sensing America Vivid 910 Non-
Contact 3D Digitizer. Details of the cobble reduction sets are provided in Table 7.1.

The scanning protocols employed are as follows: Each artefact was mounted on a
360° rotation table and scanned at arbitrary rotation angles. Multiple scans with
varying artefact orientations were then combined to form the complete models and
further processed with Geomagic Studio version 9 to refine the models and isolate
cortical areas. The models were then imported into the rendering programme
Rhinoceros (version 4.0) for calculation of surface area and volume. Figure 7.1
presents a comparison between scanned and processed models.
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Table 7.1: Summary of 3D scanning data. Materials are all silcrete. The different material categories refer to quartz clast inclusions as described in Appendix Two.
Figure 7.1: Comparison between Scanned and Fully Processed Models. Dark areas relate to cortex.
Summary of Results

Surface area as estimated using the infield recording protocols tends to provide an overestimate of true values. This effect, however, is more severe for flakes and flake fragments than it is for cores. For flakes and flake fragments the use of maximum dimension measurements always over-estimates the 2D dorsal surface of flakes. This effect is reduced, however, due to the 3D relief of each artefact’s dorsal surface. Overall, 87% (101 out of 116) of the flakes produced were overestimated producing an aggregate measure (123013 mm$^2$) that over estimates the scanned value (106196 mm$^2$) by 15.84%.

For cores, the use of the 3D measures of surface area resulted in less pronounced overestimates. For 25 out of the 30 (83%) cores measured values produced overestimates resulting in an aggregate measurement (363866 mm$^2$) that was 7.32% over the scanned value (339042 mm$^2$).

When all artefacts from the five complete cobble sets are combined, the total measured surface area (189981 mm$^2$) over estimates the scanned value (171046 mm$^2$) by 11%. These results therefore indicate that assemblage level measurements of observed surface area are biased upwards.

Measures of cortex proportion using the midpoint of the four ordinal values are also a source of data error. Here, however, error exists in the form of both over and under estimates of scanned values. While individual values are apt to vary from true values, combined the imprecision of the ordinal measures is quite low. The means of the scanned cortex percentages are slightly under the mid-point percentages of the ordinal
values (1-50% mean=21.74; 51-99% mean=74.44%). At the assemblage level, the total measured cortex proportion produces a 5.6% over-estimate of the scanned value.

When cortical surface area measurements (the combination of measured surface area and the midpoint of the ordinal measure of cortex proportion) are compared to scanned values, measured values for the five complete reduction sets are 10% greater than the scanned values. This value is very similar to the over-estimation that exists in measures of artefact surface area alone. This is because the error in cortex proportion is effectively cancelled out since artefacts with 1-25% and 50-75% cortex produce overestimates, while artefacts with 26-59% and 76-99% cortex are underestimated. This indicates that the deviation between measured and scanned quantities of cortical surface area is primarily an effect of the original overestimate in surface area created by mechanical measurement.

Because of the inherent bias in the infield recording protocols (mechanical measurement and ordinal approximation of cortex proportion), cortex ratios calculated with these values tend to produce overestimates when compared to those calculated with scanned values. This effect is demonstrated in Figure 7.2. For samples of one or two cobbles this deviation can be considerable, however, as sample size increases this effect is reduced and overestimate become consistent. For the data sets used in this study, the threshold was reached with sample sizes of five cobbles, a value that is well below the range measured archaeologically.
Figure 7.2: Difference between Mechanically Measured and Scanned Cortex Ratio against the Number of Cores. The dotted line is a reference for zero difference. The solid line is the mean difference (0.08).
This tendency for measured Cortex Ratios to be overestimates is probably a combination of the overestimate of cortical surface area as a result of mechanical measurement as well as the fact that the cortex methodology calculates estimated cortex values by assuming that cobbles were spheres (thus returning the minimum estimate of surface area per unit volume). As a result of these two factors, Cortex Ratios calculated for complete reduction sets provide values that are slightly greater than the theoretical value of one.

While this study has demonstrated that infield recording protocols tend to provide imperfect measures of true cortex values, the deviation is slight. The Scanned values (cobble frequency = 5) suggest an overestimate of about 10%, while ratios calculated during preliminary testing in Chapter Six (cobble frequency = 10) suggest an overestimate of 3%. While these errors are not unimportant, they are still relatively minor even with small samples. In order to determine the average magnitude of Cortex Ratio overestimate that can be expected archaeologically, a much larger sample of experimental data is needed. This investigation will be presented in the section that follows.

Regardless, these results indicate that even with small samples, the deviation in measured cortex values is slight enough to not unduly impact the accuracy with which cortex proportions in archaeological assemblages are interpreted. Furthermore, the error that does exist in the methodology is in fact in the opposite direction to the pattern that was identified amongst the Cortex Ratios calculated for the WNSWAP assemblages. In short, a refined assessment of the method’s operation indicates that it
is slightly biased towards the overestimate of true values, while application of this methodology to the Australian data indicates that cortical surface area is underrepresented and by a large margin. Therefore while there is bias in the measurement of cortical surface area, this bias is in fact opposite to that which would provide a false impression of the underrepresentation of cortical surface area as suggested by preliminary results.

7.2.3 Assessing Cortex Ratio Reliability

To explore the reliability of the cortex methodology a computer simulation programmed by Daniel Parker in Visual Basic and implemented on a desktop PC was developed to simulate the creation of lithic assemblages for which Cortex Ratios were then calculated. The simulation was based on the notion of exploring a null or neutral model of artefact removal (see Brantingham 2003 and Premo 2006 for similar application of a null model approach) where assemblages were created that reflected complete reduction sets (i.e. all products of core reduction were present), thus reflecting the types of assemblage variability that would be expected under conditions of complete expedition. Testing the Cortex Ratios for these simulated assemblages, allowed an examination of the likelihood that the pattern of missing cortex was a result of methodological error rather than the outcome of the selective removal of artefacts for use elsewhere.

The operation of the simulation was based on the random selection of assemblages comprised of whole reduction sets from the experimental cores. Assemblage size was within a predetermined size range – usually 500 to 1000 artefacts. This reflects the lower end of WNSWAP assemblage sizes.
The experimental cobble reduction was completed in staged intervals to provide detailed information at different points in the reduction of each cobble. Each artefact was labelled with its sequence number (i.e. 1, 2, 3 as reduction proceeded) and a list of all artefacts generated during each knapping interval was recorded. Core measurements were also made at the conclusion of each interval. As a result, for each reduction interval, the sum of all artefacts made up to that point and the characteristics of the core as measured at the interval’s conclusion, represented a complete cobble reduction (i.e. knapped cobble and artefacts produced), which theoretically should possess a Cortex Ratio of one. The random selection of multiple sets from the experimental data then produced a wide range of assemblages, each of which should theoretically have had a Cortex Ratio of one. In effect, this simple simulation replicates the testing of the cortex methodology as described in the preceding chapter. But by automating the process with larger data sets, the simulation was capable of exploring in detail the potential range of cobble combinations that could arise with the multiple sampling intervals of the 82 experimental cobbles. Furthermore, because each experimental cobble was recorded at multiple intervals throughout its reduction, the simulation was able to create assemblages reflecting a broad range of cobble reduction intensities.
Figure 7.3: Histogram of Simulation Cortex Ratios. These data indicate that while actual ratios deviate from the theoretical value of one, this deviation is slight enough that the methodology is not prone to type one error such that substantial artefact removal is indicated when indeed no such removal had occurred.

Figure 7.4: Scatter Plot of Simulation Cortex Ratios against the Flake to Core Ratio. The Pattern displayed indicates that core reduction intensity has no observable effect on the performance of the Cortex Methodology.
Through this effort 1000 experimental assemblages were created and Cortex Ratios calculated. Results are presented in Figure 7.3. These results indicate that though there is deviation from the theoretical value of one, it is largely constrained. Of the 1000 simulation assemblages created, the average Cortex Ratio was 1.095 with a standard deviation of .021.

A further test of these data was made to determine whether or not reduction intensity influenced Cortex Ratios for complete reduction sets. Figure 7.4 is a plot of the simulation Cortex Ratios against assemblage flake to core ratios. The lack of a linear trend in the point cloud clearly demonstrates that the performance of the methodology is not influenced by reduction intensity.

These results indicate that even through the cortex methodology may be imperfect, the likelihood of a false perception of artefact transport when indeed there was none is highly unlikely. In fact, not a single simulation assemblage was created with a Cortex Ratio below one. This result indicates that it is beyond the realm of statistical probability for methodological error (i.e. Type One error) to produce the pattern of missing cortex identified for a large suite of archaeological assemblages comprising over 123,000 artefacts.

A second component of the computer simulation developed for this study was the simulation of a process of random artefact removal. The aim of this component of the study was to address the question of whether or not the pattern of missing cortex necessarily implied the operation of a conscious effort to select specific forms for transport (i.e. large flakes), or whether the pattern could be created simply as a result
of the random removal of some of the products of core reduction. To address this, the simulation randomly selects artefacts for removal (between 5% and 95% of total assemblage contents) from complete simulated assemblages (as described above).

The simulated assemblages utilized in this component of the study were limited to a population size of ca. 100 artefacts. The utilisation of small population sizes was designed to speed the operation of the simulation, but does carry the added effect of exacerbating the possibility of randomly creating a deficit in cortex, in that smaller populations are more prone to the effects of chance artefact removal.

Of the 2,194,130 simulations completed, 9.89% (217,093 cases) produced Cortex Ratios that were below one, meaning 90.1% of random removals replicated the tendency for Cortex Ratios to be over one. Of the 9.89% of simulated assemblages where random removal produced a Cortex Ratio below one, 67.3% (146,074 cases) were above .9, 87.2% (189,412 cases) were above .8, and 94.5% (205,066 cases) were above .7 which approximates the highest value of .69 reported for any of the WNSWAP assemblages. In total, only 5.5% of the over 2,000,000 simulated assemblages from which artefacts were removed at random produced Cortex Ratios within the range of values recorded archaeologically for quartz and only .235% were within the range recorded for silcrete. Therefore from the results of this simulation it can be concluded that while it is not impossible for random artefact removal to deplete assemblages of quantities of cortex, it is highly improbable that Cortex Ratios such as those that are found with the WNSWAP study assemblages will be produced by chance even with very small assemblages. The Likelihood that the consistent pattern of missing cortex for lithic assemblages comprising over 123,000 artefacts
was created by a random process of artefact removal is therefore beyond the realm of statistical probability.

In summary, further testing of the cortex methodology has demonstrated that while there is error in individual data measurements, bias tends to average out in the aggregate, and that error in Cortex Ratios is consistently constrained to within a few percentage points from one. Furthermore, what little bias that does exist in the method’s operation works against the observed pattern of missing cortex, thus meaning Cortex Ratios below one are likely to be overly conservative measures of the amount of cortex that is actually missing.

While these results indicate that the basic mechanics of the cortex methodology’s operation are sound, it is important to note that the testing that was conducted in this study was completed under controlled conditions so as to isolate any potential methodological bias. In the analysis presented here, all artefacts greater than or equal to two centimetres were present in the experimental data sets and core and cobble frequencies were equivalent. The effect of these controlled conditions was that the estimation of Average Nodule Size can be made quite easily and accurately. Under experimental conditions model parameters are effectively known, while under archaeological conditions the accuracy of estimated values remains unknown. The following section addresses a course of study to refine the means by which these estimates are made, thus increasing the certainty with which the cortex method can be applied archaeologically.
7.3 Refinement of Estimates of Average Nodule Size

The accurate measurement of the size and shape of the nodules worked to produce an assemblage and therefore the cortical surface area to volume ratio of that assemblage is of the utmost importance to the successful application of the cortex methodology. Dibble et al. (2005) demonstrated that variability in the size and shape of individual nodules could be accurately represented with reference to their average size. Determining the average nodule size that existed at each of the WNSWAP study assemblages, however, presents a unique challenge.

Obviously the cobbles of stone selected for artefact production are no longer available for direct study, so the assessment of Average Nodule Size must be estimated. Sources of unworked stone provide an indication of the size ranges that were available (a factor that will be returned to later in this chapter), but it is unreasonable to assume (given the considerable size variation that exists) that cobble selection simply conformed to the average size that occurred naturally. Refitting offers the potential to investigate nodule size, however, the successful reconstruction of complete reduction sets is impractical if not impossible given the sheer volume of material in each of the many WNSWAP assemblages. Refitting may provide insights onto the original size of a few cores, but it is incapable of assessing average values at the scale of analysis completed here. Instead, what is needed is the development of a means of reconstituting Average Nodule Size that can easily be accomplished through the completion of relatively simple measurements. The best source of information for this purpose comes from the cores themselves.
Cores being reduced cobbles are necessarily smaller than the original unworked stone. However, the nature of isotrophic stone means that it fractures in fairly predictable ways and the traces acquired through reduction can serve as a basis for estimating core reduction intensity, and by extension original cobble size.

A number of studies have demonstrated that the process of core reduction leaves unique traces that are indicative of reduction intensity (e.g. Clarkson 2008; Baumler 1987). Flake scars accumulate on a core’s surface, cortex is lost and the cobble gets smaller. As reduction proceeds, the angles of existing platforms become steeper and existing platforms are eventually replaced through core rotation. In time the complexity of flake scar orientation gradually increases. Because the outcome of reduction affects these traces in different ways, their measurement provides multiple lines of evidence by which reduction can be monitored. Importantly the means by which these different processes unfold is often linear or can be made linear through simple transformation.

Researchers have taken advantage of these same effects to monitor the accumulation of similar traces on the flakes that are produced during core reduction. The relationship between the accumulation of these traces and the intensity of core reduction has served as the basis for linear regression analysis used to investigate flake sequence or stage (e.g. Bradbury and Carr 1999, Ingbar et al. 1989; Shott, 1996). These same characteristics are likely also to be of use for predicting core reduction intensity the measurement of which would allow a direct means by which the original size of reduced cobbles could be re-established.
Somewhat fortuitously, a recent body of experimental research was completed by Braun (2006) to do just this. Using experimental reduction sets, he investigated attributes related to core reduction, including scar frequency, flaking complexity and mean platform angle, in order to monitor variation in Oldowan reduction intensity. This work demonstrated that the percentage of a nodule’s mass lost through reduction could be predicted quite accurately and provided a number of useful insights into core use life in Oldowan contexts. His work was completed for use in a very different context and for very different reasons than this study, but it demonstrated an approach that had great promise for providing the measure of Average Nodule Size desired for the refinement of the cortex methodology.

The following outlines regression analysis used to investigate the suitability of the variables outlined by Braun (as well as a continuous measure of cortex proportion) for predicting the reduction intensity of Australian cores. This resulted in the development of two independent models of reduction intensity and nodule size, the performance of which were then tested with independent experimental data.

As previously noted, the progression of reduction for the experimental sets created from Australian materials was broken into several intervals for each cobble. At the conclusion of each interval a variety of measurements, including those relevant to the models produced here, were made on each core. These data reflected progressive modification throughout each core’s use life, and the staging of knapping intervals enabled an approximately even distribution of cases for the development of the regression equations. As such, the experimental data for Australian materials are very similar to those used by Braun (2006) when developing his regression models. Braun
followed a relatively strict protocol of measuring cores every time three artefacts
greater or equal to 2.5 cm in size were produced. Because reduction for the
experimental sets evaluated here was completed over a broad time range and under a
variety of different conditions, recording intervals were not as strictly defined, but
were generally completed at a rate of approximately one for every five flake
removals.

7.3.1 Attributes Recorded

The attributes recorded were selected from amongst those identified by Braun, as well
as a variety that were thought likely to be effective indicators of flaking intensity.
While a large number of attributes was recorded after each knapping interval, many
were not highly correlated with reduction intensity in the experimental data. A formal
description is limited to those that are relevant to the nodule mass regression
equations reported here.

Non-Cortical Proportion

The percentage of cortex remaining on cores from the reduction of cortical cobbles is
one of the clearest indicators of reduction intensity. Following Braun, regression
equations were based on estimating the percentage of the original nodule mass lost in
core reduction, which increases with reduction intensity. In order to have a measure
relating to cortex that also increased with reduction intensity, the inverse of cortex
proportion (non-cortical proportion) was used.
For regression analysis it was desirable to have a continuous measure of cortex proportion rather than the ordinal scale used in most lithic analyses (e.g. Roth and Dibble 1998; Gnaden and Holdaway 2000). There are a number of techniques for obtaining a continuous measure of cortex proportion, most notably photographic digitization (McPherron and Dibble 1999) and laser scanning. These, however, were ill suited to the needs of this study for a number of reasons. Photographic techniques cannot be easily applied to the measurement of cortex for three dimensional cores and the logistics and time investment of using a laser scanner in the field are prohibitive. Instead what was needed was a technique whose ease of application would enable the measurement of hundreds of cores within a single field season. In short, a simple, quick, and easily replicable measure that could stand up to field conditions was needed.

This was accomplished through the use of dot grids printed on Mylar film. The dot grid system has a long history as a tool for measuring the area of irregularly shaped features in cartography and has been similarly noted for its utility in lithic analysis (Andrefsky 1998). In measuring cortex proportions on cores, it is placed against the core’s surface and a tally of the dots with cortex and the dots without cortex is made (Figure 7.5). The core is divided into a number of different surfaces to facilitate easy and accurate measurement. In instances with particularly complex geometry, these segments may be defined with a dry erase marker. The total dots are then summed for all segments of a core’s surface. The proportion of Non-Cortical surface is then gained by dividing the number of dots that fell along non-cortical portions of the core’s surface by the total dots that were recorded. The dots are spaced at one
centimetre intervals so the total number of dots measured on a core’s surface provides a measure of the total core surface area.
Figure 7.5: Measurement of Cortex with Mylar Grid. (Dots marked in yellow are cortical, while dots marked in red are non-cortical. Non-cortical dots are divided by the total number of dots recorded to provide the percentage of a core’s surface that is non-cortical).
An evaluation of the technique’s accuracy was accomplished by comparing measures made with the Mylar grid to those obtained through the use of a laser scanner for a sample of 32 cores. Estimated cortical surface area obtained through the Mylar grid was 103.2% (S.D. 4.5) of the scanned value, thus indicating that the method provides a very close approximation of cortex proportion and surface area. Stone raw material type does not have a noticeable effect on the relationship between cortex and reduction intensity, so data for both silcrete and quartz are interpreted together. Correlations between Non-Cortical Proportion and Percent Nodule Mass Remaining are significant (% Nodule Mass Removed: Figure 7.6, r² .90, p < .001).
Figure 7.6: The Relationship between the Percentage of a Core’s Surface without Cortex and the Percentage of Nodule Mass Lost amongst the Experimental Cores.
**Scar Count Divided by Area**

An obvious consequence of the production of flakes from cobbles of stone is the accumulation of negative flake scar removals upon the surface of a core (Bradbury and Carr, 1999; Clarkson 2008; Ingbar et al. 1989; Shott, 1996). As reduction proceeds, the number of scars increases in frequency, so counts of flake scars can be used to gauge reduction intensity. Every flake scar greater than or equal to two centimetres was counted.

The accumulation of flake scars on a core’s surface does not, however, continue at a constant rate. This is because the decreasing size of a core necessarily limits the total area upon which scars can accumulate, and through continued reduction, traces of previous flake scars are gradually erased from a core’s surface (Braun et al., 2005, 2006). To account for this phenomenon, Braun (2006) transformed counts of flake scars by a measure of the core’s area. Here core area was calculated using the Mylar grid. This transformation has the added benefit of making this measurement a continuous variable. Raw material characteristics influence the accumulation of flake scars on a core’s surface, so quartz and silcrete were investigated separately.

The distribution of the variable Scar Count Divided by Area was right skewed so it was normalized with a square root transformation in order to increase the linearity of its relationship with the percentage of a core’s mass lost through reduction. The resulting variable – SQRT (Scar Count/Core Area) – is positively correlated with core reduction (Silcrete: % Nodule Mass Remaining: Figure 7.7, \( r^2 = .877, p < .001 \); Quartz: % Nodule Mass Remaining: Figure 7.8, \( r^2 = .878, p < .001 \)).
Figure 7.7: The Relationship Between the Square Root of Flake Scar Counts Divided by Core Area and the Percentage of Nodule Mass Lost amongst the Experimental Silcrete Cores.
Figure 7.8: The Relationship Between the Square Root of Flake Scar Counts Divided by Core Area and the Percentage of Nodule Mass Lost amongst the Experimental Quartz Cores.
Exploitation Surfaces

A consequence of the process of continued core reduction is the phenomenon known as core rotation, where a core is rotated in order to continue flaking after a previous platform is no longer suitable for further removals. As a result of core rotation, the orientations of flakes scars that accumulate on the core’s surface begin to originate from an increasing number of directions.

Braun (2006:73) developed the attribute “Exploitation Surfaces” to quantify this phenomenon. By his definition, exploitation surfaces represent “surfaces of the core where removals are consistently being removed in the same plane”, and relate to the axis from which a flake is removed (Figure 7.9). The potential variation in flake axes is continuous, so Braun chose the arbitrary division of 30 degrees (as determined with a goniometer) to separate exploitation surfaces. Flakes struck from the same core platform but with an axis of percussion that differs by 30 degrees or more are considered to be from separate exploitation surfaces.
Figure 7.9: Diagram of the Attribute Exploitation Surface. (Arrows denote the axes of Exploitation Surfaces One and Two)
This is a particularly complex attribute so some additional discussion of how it was put into operation is in order. The operationalisation of this attribute may deviate somewhat from that used by Braun in his study. What is of importance is that the recording protocols used in this study were consistent between the different recorders both during the measurement of experimental sets and in subsequent application to archaeological materials.

Recording started by first selecting an initial exploitation surface; this was generally that relating to the largest flake scar on the core. The core was then rotated in relation to the axis of this surface, to identify additional scars with flaking axes originating from the same surface. It is important to note that the identification of an exploitation surface was not contingent upon the identification of a point of flake initiation, but was instead made on the basis of a generalized interpretation of the flaking axis as identified by undulations on the scar’s surface as well as a variety of other indicators such as flake scar margins. With all scars from one surface identified, an additional scar originating from a separate exploitation surface was then chosen and all scars with similar axes were then identified. This process was repeated until all flake scars in excess of two cm had been assigned to an exploitation surface on the core. While this process is potentially quite demanding, the majority of cores had between two and three surfaces making surface identification a relatively straightforward process. In instances where heavily reduced cores possessed particularly complicated flaking patterns, the identification of exploitation surfaces was occasionally facilitated by marking out the axis of each flake from the same surface with a dry erase marker. By marking all flakes from each surface as they were recorded, the identification of additional surfaces was thus limited to unmarked flake scars.
Like counts of flake scars, the relationship between reduction intensity and exploitation surface frequency is complicated by core size. Again larger cores necessarily have greater area to register different flaking surfaces, and through continued reduction, traces of previous flake scars are gradually erased from the surfaces of individual cores as they decrease in size (Braun et al., 2005, 2006). As with flake scars, this phenomenon was corrected through division by core area. The relationship between this variable and the percentage of nodule mass lost in the experimental data was also curvilinear, but to a greater extent than that of the flake scar data. Linearization of this attribute was accomplished with a log natural transformation. The resulting variable – Log Natural (Exploitation Surfaces/Core Area) – is positively correlated with core reduction (Silcrete: % Nodule Mass Remaining; Figure 7.10, $r^2 = .825$, p < .000; Quartz: % Nodule Mass Remaining: Figure 7.11, $r^2 = .765$, p < .000).
Figure 7.10: The Relationship Between the Log Natural Transformation of Exploitation Surfaces Divided by Core Area and the Percentage of Nodule Mass Lost amongst the Experimental Silcrete Cores.
Figure 7.11: The Relationship Between the Log Natural Transformation of Exploitation Surfaces Divided by Core Area and the Percentage of Nodule Mass Lost amongst the Experimental Quartz Cores.
Exploitation Surface Interaction

The attribute Exploitation Surface Interactions marks the convergence of flake scars struck from different exploitation surfaces. In discussion of the previous attribute it was noted that increased core reduction resulted in an increase in the range of different flaking axes found on a core’s surface. As reduction continues, these different surfaces will converge creating overlapping patterns of flake scars struck from different exploitation surfaces (Figure 7.12). This is recorded as the total number of unique combinations of exploitation surface convergences (e.g. 1:2, 1:3, 2:3).
Figure 7.12: Exploitation Surface Interactions. (The red dot denotes the convergence between the two separate Exploitation Surfaces represented by the dotted arrows)
This variable is technically, ordinal, in that differences between counts are not of an equal interval. This attribute is, however, an approximation of a continuous phenomenon – the convergence of flaking axes on a core’s surface through core rotation and it displays a positive relationship with increased core reduction with linearization through a square root transformation. The resulting variable is positively correlated with core reduction (Figures 7.13, 7.14; Silcrete: % Nodule Mass Remaining: $r^2 = .784$, $p < .001$; Quartz: % Nodule Mass Remaining: $r^2 = .652$, $p < .001$).
Figure 7.13: The Relationship Between the Square Root of Exploitation Surface Interactions and the Percentage of Nodule Mass Lost amongst the Experimental Silcrete Cores.
7.3.2 Regression Analysis

Figure 7.14: The Relationship Between the Square Root of Exploitation Surface Interactions and the Percentage of Nodule Mass Lost amongst the Experimental Quartz Cores.
These four variables are all useful for estimating the intensity of core reduction in the Australian assemblages. In initial analysis, however, it was discovered that non-cortical proportion had the greatest predictive power for the development of regression models to estimate the percentage of a nodule’s mass removed through reduction. While this is desirable, its inclusion in multiple linear regression models has the effect of marginalizing the contribution of the other variables. Comparison of models computed with various combinations of all variables performed only marginally better than simple regressions based on non-cortical proportion alone, and in most cases the remaining variables lacked significance at the .05 level. Additionally, the inclusion of the additional variables in analysis had the disadvantage of creating high collinearity and observations of standardized coefficients indicated that the relative contribution of these variables to the resulting estimates was marginal. For this reason it was decided to compute separate regressions, one based solely on non-cortical proportion and another making use of the remaining attributes.

Doing this has the added benefit of creating two independent estimates for average nodule size for use in computing Cortex Ratios, meaning two separate Cortex Ratios can now be calculated for each of the archaeological assemblages. The advantage of separate independent estimates is that it increases the level of certainty with which assessments of cortex proportions in archaeological assemblages are made. A close agreement between the two estimates would provide further certainty that average nodule size has been gauged accurately, while disagreement would provide a note of caution about the interpretative value of results.

_non-cortical Regression_
The relationship between non-cortical proportion and reduction intensity is complicated by the fact that the slope of the line between non-cortical proportion and the percentage of nodule mass removed decreases once the majority of cortex is removed. During initial core reduction any removal of mass will automatically result in a slight removal of cortex meaning the slope of the line between the two values approximates one. This parity continues throughout most of the reduction, however, as the non-cortical proportion increases, the relationship between it and the percentage of mass lost becomes much more variable, an obvious example being when cortex is completely removed mass still remains. Furthermore, as the intensity of core reduction proceeds, a point is reached where it becomes increasingly difficult to create viable flakes. The effect is that few cores are reduced to the point where only single percentage points of their original mass remain, while a much larger proportion of cores are reduced to the point where only a few percentage points of cortex are remaining, meaning the ratio of the non-cortical proportion to nodule mass lost is generally less than one for extensively reduced cores. As this effect is unlikely to occur until the very latter stages of reduction, the majority of cores are unlikely to have a ratio of non-cortical proportion to nodule mass lost significantly below one and simple regressions are likely to produce coefficients very near one. While such models would accurately reflect the relationship between cortex proportion and reduction intensity for the majority of cores, there is a tendency towards overestimate for those cores most intensively reduced. This can be demonstrated by plotting the residuals of the predicted values for a regression of the percentage of cortex removed on the percentage of nodule mass removed (Figure 7.15).
Figure 7.15: The Relationship Between the Residual Values of the Predicted Percentage Nodule Mass Removed and Non-cortical Proportion for the Experimental Cores. Line indicates 85% non-cortical proportion.

Because the ratio of mass lost to cortex lost decreases when a core’s cortex percentage becomes quite low, predicted values for percentage of mass lost on these cores tend to
be over estimates. Furthermore, error in predicted percentage of mass lost has a much larger affect on predicted values as reduction increases. This can be best illustrated through an example. If a core weighs 65g and is predicted to have lost 6% of its mass when in reality it has only lost one percent, the predicted nodule mass will be 69.15. This means nodule mass is overestimated by a little more than five percent. Predicting that the core has lost 99% of its mass when in reality it has only lost 94% gives a predicted value of 6500 grams when true nodule mass is 1083 grams a 600% difference. While the regression model performs well in the vast majority of cases, gross overestimates can occur for cores with minimal to no remaining cortex and this will affect the accuracy of subsequent average nodule estimates.

Based on the plot of residuals (Figure 7.15), the point where the model begins to result in a consistent overestimate occurs around the 85% non-cortical threshold. As a consequence, separate regressions are calculated for cores with non-cortical proportions below 85% and those with values above 85%. Finally, in the scatter plot of the non-cortical proportion and the percentage of nodule mass removed (Figure 7.6), there is a slight heteroscedasticity in the distribution of the data, for this reason the square root of both variables is used in analysis.

The regression line of the resulting models passes through the origin, because it is not possible to have a negative core reduction, and a non-cortical proportion of zero necessarily equates to no lost nodule mass. The models show a strong correlation between non-cortical proportion and percentage of nodule mass lost (Less than 85% Non-Cortical $r^2$: .981; standard error: .086; p < .000; Greater than 85% Non-Cortical $r^2$: .996; standard error .056; p < .000).
The resulting models are:

- **Less than 85% Non-cortical**: Percentage of Nodule Mass Lost During Reduction = \((\text{Square Root Non-cortical Proportion } \times 0.978)^2\);

- **Greater than 85% Non-Cortical**: Percentage of Nodule Mass Lost During Reduction = \((\text{Square Root Non-Cortical Proportion } \times 0.914)^2\);

The regressions are based around predicting the square root of the percentage of a nodule’s mass lost, so values have to be squared to provide actual estimates. After correction, the maximum overestimate of the percentage of nodule mass lost is by 30% and the maximum underestimate by 36%. While this demonstrates a potential for considerable error for individual cases, overall the mean difference in the experimental data is only 0.002%. An evaluation of the residuals (Figure 7.16) also shows that although estimates are at times in error by a considerable margin, the average value is quite accurate. The results presented here suggest that the use of this model can quite accurately predict the percentage of the original nodule mass lost though reduction.
Figure 7.16: The Relationship between the Studentized Residual Values of the Predicted Square Root of the Percentage of Nodule Mass Removed and the Predicted Square Root of the Percentage of Nodule Mass Removed for the Experimental Cores.
Multiple Linear Regression

To analyse the remaining variables, a stepwise technique was used in order to find a model with the simplest combination of independent variables and the lowest standard error. In the non-cortical proportion model, quartz and silcrete data were combined because the relationship between cortex and reduction intensity did not deviate between the two raw material types. However in the remaining models, there is a difference between raw material types, so separate regressions are computed.

For silcrete, a regression using the variables Square Root of Scar Count Divided by Core Area, the Square Root of Exploitation Surface Interactions and the Log Natural transformation of Exploitation Surfaces divided by core area produced the best result. The intercept is kept at the origin so that the resulting relationship does not predict negative values. The resulting model shows a strong correlation with the percentage of nodule mass lost (Adjusted $r^2$: .956; standard error: .12; p < .000) and colinearity gives a condition index of 5.25, which is well within the conventionally accepted range of under a value of 15 (Larson and Finnley 2004).

The resulting model is:

- Percentage of Nodule Mass Lost During Reduction = (Square Root of Scar Count Divided by Core Area x 1.271) + (Square Root of Exploitation Surface Interactions x .111) + (Log Natural transformation of exploitation surfaces divided by core area x -.010)
The maximum overestimate of the percentage of nodule mass lost is 28% and the maximum underestimate is 22%. While this demonstrates the potential for considerable error, the mean difference in the experimental data was .0006% under the actual value. An evaluation of the residuals (Figure 7.17) shows that although estimates are at times in error by a considerable margin, the model is not inherently biased. The results presented here suggest the use of this model can quite accurately predict the percentage of the original nodule mass that was lost though reduction.
Figure 7.17: The Relationship Between the Studentized Residual Values of the Percentage of Nodule Mass Removed and the Predicted Percentage of Nodule Mass Removed for the Experimental Silcrete Cores.
For Quartz a regression using the variables Square Root of Scar Count Divided by Core Area and Log Natural transformation of exploitation surfaces divided by core area was found to produce the best result. This model places the intercept through the origin to prevent the prediction of negative values. The resulting models show a strong correlation between non-cortical proportion and percentage of nodule mass lost (Adjusted $r^2: .940$; standard error: .118; $p < .000$). Furthermore an evaluation of colinearity gives a condition index of 3.23, which is well within the conventionally accepted value of under 15 (Larson and Finnley 2004)

The resulting model is:

- Percentage of Nodule Mass Lost During Reduction = (Square Root of Scar Count Divided by Core Area x 1.814) + (Log Natural transformation of exploitation surfaces divided by core area x .019)

The maximum overestimate of the percentage of nodule mass lost is 21% and the maximum underestimate is by 21%. While this demonstrates the potential for considerable error in individual cases, the mean difference in the experimental data was .00001% under the actual value. An evaluation of the residuals (Figure 7.18) further demonstrates that although estimates are at times in error by a considerable margin, the model is not inherently biased. The results presented here suggest that the use this model can quite accurately predict the percentage of the original nodule mass lost though reduction.
Figure 7.18: The Relationship Between the Studentized Residual Values of the Percentage of Nodule Mass Removed and the Predicted Percentage of Nodule Mass Removed for the Experimental Quartz Cores.
The best test of a model’s accuracy is an evaluation of its performance using data not used in the creation of the model (Shennan 2001). A total of 49 silcrete and 32 quartz core reductions were sampled at random from the experimental data and set aside for this purpose. Results from this comparison (Table 7.2) demonstrate that these models predict actual nodule mass quite well, thus adding further assurance of the predictive power of the methods developed in this study.

<table>
<thead>
<tr>
<th>Material</th>
<th>N</th>
<th>Nodule Mass</th>
<th>Predicted Nodule Mass (Cortex)</th>
<th>Predicted Nodule Mass (MLR)</th>
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<tbody>
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<td>265.62</td>
<td>243.5</td>
<td>255.5</td>
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<td></td>
<td></td>
<td>245.63</td>
<td>271.73</td>
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<td></td>
<td></td>
<td>467.34</td>
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<td>730.79</td>
</tr>
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</table>

Table 7.2: Test of the performance of the experimental regression using additional data not used in the development of the regression equations.

### 7.4 An alternative Approach to the Measurement of Cortex

The strong correlation between the regression models and core reduction intensity and successful test with independent data suggests that these models will provide an accurate measure of the original size of cores prior to reduction therefore improving the certainty with which cortex is measured in the WNSWAP assemblages. While these models perform admirably, they remain estimates. While the use of estimates is an unavoidable reality of interpreting the original size of cobbles, it would nevertheless be useful to have an alternative means of assessing the question of underrepresented cortical surface area, especially one that operated without making assumptions of the size of the cobbles from which artefacts were produced.

One way of examining cortex proportions without recourse to an estimate of average nodule size is by determining the size of a nodule of stone with cortex and volume...
(i.e. cortex to volume ratio) in equal proportion to that measured amongst the artefacts within an assemblage. Determining this value effectively asks: How big would cobbles have to have been on average to produce the cortex proportions measured in an assemblage under conditions of complete technological expedience?

Mathematically this may be expressed as:

Size of nodule = \(36\pi \left(\frac{V}{SA}\right)^3\)

where \(V/SA\) is the volume to surface area ratio.

Because the initial results indicated that cortex is underrepresented from all of the WNSWAP study assemblages, solving this equation for each assemblage resulted in increased estimates of nodule size. Results are presented in Table 7.3, including the implied average reduction intensity these values require for the cores measured in each assemblage (mean core mass/ estimated nodule size). These measures of nodule size seem quite large, especially for silcrete. While this in itself adds support for the patterning of missing cortex, it would be very useful to know how easily cobbles approaching these sizes can be obtained in each study location.
<table>
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<th>Assemblage</th>
<th>CN1</th>
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<th>ND</th>
<th>SC</th>
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<th>RH</th>
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<td>Q</td>
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<td>Q</td>
<td>S</td>
<td>S</td>
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<tr>
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<td>565</td>
<td>616</td>
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<td>435</td>
<td>246</td>
<td>315</td>
<td>1577</td>
<td>4464</td>
<td>3540</td>
<td>4691</td>
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<tr>
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<td>0.94</td>
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<td>0.96</td>
</tr>
</tbody>
</table>

Table 7.3: Nodule Mass with Cortical Surface Area and Volume in Proportion to that Observe in the Lithic Assemblage.
To establish both a point of comparison with which to further evaluate estimated Average Nodule Size determined through regression and to investigate the relative abundance of cobbles of a size large enough to have cortex and volume in equal proportion to that measured in archaeological assemblages, an understanding of the natural size distribution of the cobbles that were available for artefact production in each area is needed. To accomplish this, I utilized a method for assessing cobble size distributions within deposits of stone.

7.4.1 The Wolman Pebble Count

A sampling technique known as the Wolman method or Wolman pebble count (Wolman 1954) can be used to quickly develop a frequency distribution of cobbles of stone in the various raw material features that surround the individual WNSWAP study assemblages. The method is based on obtaining a small sample of the stones (typical ca.100 samples) distributed within a given sampling locale and then measuring the size of each one. The simplicity and accuracy of the original method has established it as a standard technique in a wide array of geomorphological and biological applications (e.g. Carling 1988; Doyle et al. 2003; Flintham and Robert 1988; Haslam 1978; Leopold 1970; Rice et al., 2001).

Collection at each sampling location proceeds by first dividing the area into about 100 units in order to obtain an even coverage (Wolman 1954). Establishing these units can be obtained by gridding with meter tapes, but frequently relies on walking parallel transects over the sampling area. Cobble selection at each sampling interval is done by reaching down and selecting the first stone touched by the forefinger while
reaching over the foot (Figure 7.19). In order to avoid bias in selection, the operator’s eyes are averted while the finger is being placed. Measurement of stone size is then recorded and the stone is then cast aside.
Figure 7.19: Sample Selection for the Wolman Pebble Count as Applied in this Study. (Note that samples are collected with eyes averted to avoid sampling bias)
The use of this method for investigating the pattern of missing cortex, however, required a few modifications to conventional protocols. Because research was focused on the size distribution of cobbles used for flaked stone artefact production, the lower range of particles commonly sampled in other uses of the Wolman method was truncated. Determining a minimum cobble size threshold selected in the past involves looking at the lower end of nodule weights predicted from cores retaining greater than 50% cortex. The vast majority of these cobbles are greater than 30 grams. While smaller cobbles were undoubtedly used, this serves as a conservative but not unreasonable approximation of the minimum size of cobble selected for reduction in the WNSWAP study areas.

The stone particle size data generated through this technique are usually analyzed as frequency distributions of different classes (relating to standard sieve sizes used in other sampling techniques), and are most often based on the length of a cobble’s b-axis (the second longest cobble dimension). For this study the interest was not in cobble dimensions but volume as determined by dividing mass by material density. For this reason cobble weight was used as the size measurement.

7.5 Conclusion

This chapter provides a more in-depth test of the pattern of underrepresented cortex presented in Chapter Six. The outcome of this additional study was (1) it was demonstrated that the precision and accuracy of the archaeological data from which cortex proportions are interpreted were sufficient and that the general operation of the cortex methodology was sound, and (2) the development of refined techniques for
determining the variable of critical importance to the cortex methodology’s operation, Average nodule Size.

Experimental testing with laser scanning and computer simulation demonstrated that though imperfect, the cortex methodology can accurately assess cortex proportions in archaeological assemblages. The bias that was discovered to exist in the cortex methodology is such that observed cortical surface area is an overestimate of true values. Therefore Cortex Ratios below one are apt to be conservative estimates, making any indication of underrepresented cortical surface area all the more conclusive.

The methodologies outlined in this chapter provide a more refined approach to assessing the validity of the pattern of missing cortex identified during the initial application of the cortex methodology to the WNSWAP assemblage data. The successful development and independent evaluation of the regression equations presented here offers a more refined estimate of the variable Average Nodule Size, while the employment of the Wolman pebble count provides an alternative vantage onto the proportions of cortical surface area observed in the WNSWAP study assemblages. The application of these methodologies through the completion of additional field work at a sample of the WNSWAP study areas will be presented in the following chapter.
Chapter Eight

Additional Fieldwork
8.1 Introduction

The preceding chapter outlined the use and development of methods to investigate the variable of critical importance to the operation of the cortex methodology, Average Nodule Size. This chapter will discuss the field work component of this thesis in which these methodologies were applied to assemblages previously investigated by the Western New South Wales Archaeological Programme (WNSWAP).

Field study to complete additional measurements on cores and to assess raw material size distributions was completed in three separate field seasons, each spent at one of three study areas previously investigated by WNSWAP: Paroo-Darling National Park, Fowlers Gap Arid Zone Research Station and the Pine Point and Langwell pastoral properties. Because of time and budgetary constraints, it was not possible to reinvestigate every study assemblage analyzed by WNSWAP over the past 13 years. Instead, the investigations sampled a diverse range of the assemblages from the larger suite of WNSWAP study localities in order to provide further clarity about the patterning in cortical surface area identified in the initial study presented in Chapter Six. The aim was to use the refined methodology to provide a test of the validity of earlier results for a sample of the WNSWAP assemblages. The outcome provided clarity on to the broader pattern identified amongst the larger 123,000 artefact dataset. The three study areas selected represented the best fit between the desire to sample a large diversity of contexts and the limited time that could be spent in the field.

Descriptions of these study locations are provided in Chapter Four. Description of the protocols for core selection and stone raw material survey along with summary
information for the analyses completed at each individual study location are provided in this chapter.

8.2 Field Methods

8.2.1 The Identification of Cores

In its simplest conceptualization, a core is simply a nucleus of stone from which flakes have been removed, which in theory separates flakes and flake tools from the cores from which they were generated. However, this definition often fails when confronted with the realities of archaeological assemblage variability. Nodules of stone from which flakes were struck served not only as a source of flakes (and flake fragments) for use as tools, but also as tools themselves, while flakes could be further modified to serve as cores (see Hiscock 2006 for further discussion of this phenomenon and Hayden 1979 for ethnographic demonstration). A variety of artefact forms therefore technically meet the simple core definition. The point is not to belabour the fluidity of archaeological definitions, but to instead highlight the fact that choices about classification should be ordered to suit the specific goals of analysis. The selection of cores in this study was focused on identifying cobbles of stone that had been worked to produce the flakes and flake fragments represented in the WNSWAP data. In order to meet these goals, certain forms (though technically cores according to the above definition) were excluded from examination. These include, bipolar cores, those cores lacking areas of scarring that were greater than or equal to two centimetres in maximum dimension and flake cores.
Here the term bipolar core relates to small unworked gibbers (i.e. gravels) that were knapped using a hammerstone and anvil. Cores matching this description were excluded from analysis because they were seldom the source of more than one or two flakes and are also generally much smaller than the cobbles from which the bulk of flake products in an assemblage were produced. Because proportionally each bipolar core was a limited source of flakes, placing them on an equal footing with cores that were the source of a far larger number of flakes would have unduly influenced the estimate of the average size of the cobbles used to produce an assemblage. Bipolar cores contributed little to the total quantity of stone measured in an assemblage so their inclusion in average nodule size estimates would necessarily bias predicted values downward.

Similarly, within the western NSW assemblages there are often “gibbers” from which a number of small flakes were removed. Though these “core tools” could have served as a source for small flakes that were used (Dibble and McPherron 2006), the two centimeter clast size threshold used in WNSWAP recording protocols means that these cores would not have contributed to the pool of artefacts from which the analysis of cortex was made. As demonstrated in the preceding chapter, continued reduction will erase earlier flake scars thus creating a gradual diminution in the size of flake scars as cores become more heavily worked. For this reason, the criterion for the inclusion of a core in this study was the possession of a continuous area of flake removal greater than or equal to two centimetres. That is, this area could relate to both individual flake scars as well as areas of overlapping flake scars. Cores not meeting this criterion were excluded from analysis.
Finally, flake cores, though a source of flakes themselves, are the product of the nodular cores that are of interest to this study. For this reason, they have been excluded from analysis.

In short, analysis was limited to those cores capable of providing a vantage onto cobbles whose reduction defined the relationship between cortical surface area and volume observed in each of the WNSWAP assemblages. Because preliminary investigation suggested that cortex was underrepresented in each of these assemblages, extra effort was made to ensure against the inclusion of cores that would unduly decrease the estimate of Average Nodule Size.

8.2.2 Core Sampling

Though point provenience information exists for each core within the larger WNSWAP database, it was impractical given the large number of assemblages from which cores were to be sampled to re-establish the grid system necessary for the location of individual cores. Instead a representative sample of cores was obtained from within each study location. The general pattern of sampling was held constant between assemblages, however, sampling intensity was varied to suit the conditions of each individual study location. As a result, the total number of cores for which the experimental core attributes were recorded in each assemblage was a consequence of core density, total assemblages size and the amount of time over which field work was conducted in each study area.
The general sampling protocol is as follows. At each study location, the boundaries of the previous survey locations were re-established with existing coordinates and a handheld GPS. Where assemblage boundaries were established on the basis of a grid system or through the use of natural features (e.g. creek lines or scald boundaries), the process of re-establishment was rather straightforward. In other instances where survey boundaries were less easily defined, re-establishment was enabled through the use of the coordinates of individual artefacts to form a perimeter, which was demarcated with either pin flags or nails fixed with survey tape. With boundaries re-established, sampling of cores within the assemblage then began.

Where assemblages represented small continuous features (i.e. 100’s of square meters), cores were sampled in order to provide systematic coverage of the entire area within the previous survey boundaries. For larger survey areas (i.e. 1000’s of square meters), separate sampling areas were established to subsample core variability from multiple locations across the larger study location. The representativeness of the samples between larger and smaller study locations was similar, the sampling intensity for larger areas, however, was likely lower than that for the smaller study locations.

A number of sampling nodes were located to provide a good areal coverage within the established boundaries, and all cores were selected within a set number of meters from each node (decisions about spacing of nodes and their spatial extent were determined for each study location and were contingent on infield estimations of artefact density). The density of cores sampled across each study location approximated the actual variation that exists within each assemblage. That is, more
cores were sampled in areas of higher density, while fewer were sampled from areas of lower density.

The cores selected for sampling were then assigned an identification number written on a paper luggage label and stuck in the ground with a nail marking the location of the core. The measurement of the additional core attributes was completed and logged into a PDA. Once analysis was completed, all cores were photographed. A brief overview of the application of these protocols at each study location follows.

8.2.3 Minimum Analytical Nodule Analysis

A Minimum Analytical Nodule Analysis (MANA) (e.g. Larson and Finnley 2004) was undertaken between the cores sampled from each study location. This was used to test the general relationship of one core per nodule enabling the equation of core frequency with nodule frequency. This has relevance for the application of the cortex methodology where additional core measures were not completed. It is also relevant to the investigation of raw material size distributions discussed in Chapter Nine.

Because Minimum Analytical Nodule Analysis has the potential for observer bias, efforts were made to assess the ease with which the technique could be used to accurately link artefacts back to an individual nodule. The technique was applied to a large body of experimental refit sets, including the experimental reduction sets used to develop the core measurements and others from the teaching collections housed at the University of Auckland. While not quantified, the success with which artifacts could
be accurately linked to cobbles provided confidence in the ability to identify cobbles that were likely from the same nodule.

All cores from each assemblage (or in the case of spatially extensive assemblages, within each sampling unit), were compared to determine the likelihood that different cores were created from the same nodule. Because of the requirement of Aboriginal constodians that all artefacts be returned following analysis, comparison was facilitated by placing each core in a plastic bag marked with the identification number (Figure 8.1). All cores were then compared to determine the likelihood of multiple cores originating from the same cobble. Following Larson and Finnley (2004), determinations were made on the basis of colour, texture, inclusions, and when present, exterior cortex.

The considerable colour variation that exists in silcrete made this process relatively simple. Quartz proved more of a challenge because of greater uniformity in colour. Slight variations, however, makes it possible to easily distinguish between different cobbles on the basis of color and texture alone in most cases. Cortex characteristics and the identification of residual cortex on multiple opposing sides (thus eliminating the potential for conjoins with other cores) helped to further refine investigation when cores could not be distinguished on the basis of colour and texture alone.
Figure 8.1: Minimum Analytical Nodule Analysis. (A: Plastic bags and Luggage Labels B: Core to Core Comparison).
8.2.4 Stone Raw Material Survey

Raw material surveys described in Chapter Seven indicate the natural size distribution of stone available for artefact production. Quantifying these size distributions helped to assess the validity of estimates of average nodule size while also providing the necessary information to compare the relationship between cortical surface area and volume found in each assemblage with that same relationship as it exists naturally for the stone sources from which artefacts were produced.

Sources of silcrete and quartz cobbles are distributed widely within each of the WNSWAP study areas so it is not possible to gain a systematic sample of the size range of cobbles for all of the stone in the vicinity of each study assemblage. Instead investigation of raw material size targeted specific areas to determine whether or not stones that were large enough to have surface area and volume in proportion to that observed in artefact assemblages were present in large enough proportions to have reasonably been the source of cobbles used to produce artefacts. Because of this, areas with the largest stone that could be obtained within a short distance from each study area were targeted. Raw materials certainly could be carried from place to place (e.g. Webb 1993), meaning larger stones could have been introduced from elsewhere, but the abundance of local materials would require Aboriginal populations to have placed considerable effort in importing stone from one source to another. As previously stated, the raw material composition of the assemblages resembles those that can be obtained locally, so the importation of large quantities of indistinguishable raw materials from one source to another seems highly unlikely.
The Wolman pebble count (Wolman 1954) is based on obtaining a small sample of the stones (typically 100 samples) distributed within a given sampling locale. Application of the technique is as follows: Transects were walked and spacing intervals determined to collect 100 samples evenly over the area to be sampled. For particularly large areas, several samples were taken. Only cobbles of silcrete and quartzite were sampled. In the event that a selected cobble was not silcrete or quartz, it was cast aside and an additional sample was taken at that interval.

Cobble mass was recorded to the nearest gram using a portable scale and individual weights were used as opposed to classes in order to retain greater precision. These values were then recoded using the same data software used in the core analysis.

8.3 Field work at the WNSWAP study areas

Detailed discussion of the context and archaeological materials at each study location was provided in Chapter Four, so the information reported here is limited to the specific details relevant to the additional work completed for this study.

8.3.1 Fowlers Gap

At Fowlers Gap, the study locations used were Fowlers Creek, Mulga Dam, Nundooka, and Sandy Creek (see Chapter Four Figure 4.3). Each is described below.

Fowlers Creek (FC) The boundaries of the 200 by 150 meter archaeological survey area were re-established with GPS. A preliminary survey of cores was completed to
determine the sampling density, and sampling locations were marked out within the survey boundaries. Cores were relocated within these units and marked with nails. A minimum analytical nodule analysis was completed and the cores measured, photographed, and returned to their original location. This effort resulted in the analysis of 54 quartz cores.

While Quartz cobbles are available in the Fowlers Creek channel bed, the bed was largely obscured by sediment and the extensive gibber pavements that cover the survey area contained cobbles identical to those from which cores were produced. In fact, cores were found throughout the area to the Northwest of the FC assemblage boundary chosen for raw material survey (it was therefore necessary to first check each sample to determine that it was indeed unworked). One sample of 100 quartz cobbles was collected at this survey location.
Figure 8.2: Fowlers Creek (FC) Survey Location. (A) Map of Study Area with Hearth and Survey Boundaries; (B) View of Study Area; (C) View of Raw Material Survey Area; (D) Photo of Pebble Count Sample.
Mulga Dam (MD) A rectangular area encompassing the 300 by 100 meter extent of the previous survey boundaries was established with GPS. A preliminary survey of cores was then completed and sampling locations were then established to provide a representative coverage of the survey area. Cores were located within each area and marked with nails. A minimum analytical nodule analysis was completed, core measurements were made, cores were photographed, and all cores then returned to their original location.

Thirty nine quartz and four silcrete cores were analysed. One sample of 100 quartz cobbles was taken from a gravel bar in Sandy Creek approximately 150 meters from the MD study assemblage.
Figure 8.3: Mulga Dam (MD) Survey Location. (A) View of Study Area; (B) Map of Study Area with Hearth and Survey Boundaries; (C) View of Raw Material Survey Area; (D) Photo of Pebble Count Sample.
Nundooka (ND) The boundaries of the 200 by 50 meter archaeological survey were re-established with GPS. A preliminary survey of cores was completed and sampling locations were established. Cores were then located and marked with nails. A sample of 44 quartz and 27 silcrete cores was then taken, analyzed, photographed and returned.

Raw material surveys were completed along the hills immediately above the study assemblages. Because of the large size of this area, three samples were taken at different locations within the greater area. Silcrete was in modest proportions so sampling was completed to get 100 quartz cobbles for each location. A separate random walk was then completed over the area encompassed by the three areas, counting only silcrete until the remaining numbers needed to get 100 had been obtained.
Figure 8.4: Nundooka (ND) Survey Location. (A) Map of Study Area with Hearth and Survey Boundaries; (B) View Looking over towards Study Area from Raw Material Survey Area; (C) View of Raw Material Survey Area.
Sandy Creek (SC) The Sandy Creek study area relates to an extensive scalded area along a one kilometre stretch of Sandy Creek. Four separate areas along the creek were targeted for the previous archaeological survey. GPS was used to relocate the general boundaries of each of the four survey areas. The necessary sampling densities were assessed, sampling units were established and cores were located with nails. A total of 83 quartz and eight silcrete cores were selected for the completion of further analysis, these were then analyzed, photographed and returned.

Quartz is available in abundance in the area in the form of extensive cobble bars in the creek bed and within gibber pavements distributed along the hillslopes on either side of the floodplain. Three samples of quartz cobbles were taken from the creek line and one was taken along a gibber hillslope adjacent to the easternmost artefact survey area.
Figure 8.5: Sandy Creek (SC) Survey Location. (A) Map of Study Area with Hearth and Survey Boundaries; (B) View Looking Towards Study Area; (C) View of Raw Material Survey Area; (D) Photo of Pebble Count Sample.
8.3.2 Paroo-Darling

At Paroo-Darling National Park, the study locations targeted for further field study were Charlton Well and Round Hill (see Chapter Four Figure 4.4). Time constraints precluded a reassessment of cores from the North Peery assemblage.

Charlton Well (CW) A grid system of previously selected points was established over the previous survey area at CW with a GPS. Cores were then sampled within each of these grid units at an intensity in proportion to the number measured within that unit during the previous study. This resulted in the selection of 106 silcrete cores. Minimum Analytical Nodule Analysis was then completed for these cores, additional core measurements made, cores were photographed and then all materials were returned to their original location.

The majority of lithic artefacts were probably produced from locally abundant silcrete cobbles collected from the bed and banks of Peery Creek. Visual inspection of these materials shows clear similarity between the characteristics of these cobbles and those reduced to produce the assemblage. The contemporary creek bed is obscured by fine sediments over much of its course, but does have exposed cobble beds in a variety of locations. The cobble bed nearest to the study assemblages was chosen and sampled. Only silcrete was found in the location, so sampling stopped once 100 cobbles greater than or equal to 30 grams had been obtained.
Figure 8.6: Charlton Well (CW) Survey Location. (A) Map of Study Area with Hearth and Survey Boundaries; (B) View of Raw Material Survey Area; (C) Photo of Pebble Count Sample; (D) View looking towards Study Area.
Round Hill (RH) During the previous WNSWAP study at RH, three separate survey areas were targeted. For the reanalysis for this study, the approximate boundaries of two of these locations were re-established with a GPS (Figure 8.7 A). Cores were selected to provide a representative areal sample within each location. A total of 78 silcrete cores were analyzed, photographed, and replaced. Two raw material surveys of silcrete cobbles were obtained from the area, one at each survey unit.
Figure 8.7: Round Hill (RH) Survey Location. (A) Map of Study Area with Hearth and Survey Boundaries; (B) View of Study Area; (C) View of Study Area; (D) Photo of Pebble Count Sample.
8.3.3 Pine Point Langwell

At Pine Point Langwell, each of the five study locations analysed by Shiner (2004), Conservation One and Three, Kars One and Two and Silcrete Quarry One were re-examined (see Chapter Four Figure 4.5).

*Conservation One and Three (CN1 and CN3)*

These study locations reflect two separate areas along a two kilometre stretch of Pine Creek. First the general boundaries of each were re-established. These represent a very large area marked by scalds with discrete boundaries. A survey was completed to mark the location of scalded areas within each area. A sample of these scalded areas was then selected in order to gain a representative spatial sample of the artefact variability within each study location. Cores within these scalded areas were then identified, analysed, photographed and returned to their original location. This effort resulted in 61 quartz and four silcrete cores from CN1 (northern half) and 61 quartz and six silcrete cores from CN3 (southern half).
Figure 8.8: Conservation (CN) Survey Location. (A) Map of Study Area Boundaries; (B) Typical View of Scalded Areas within Study Area; (C) View of Raw Material Sampling Location; (D) Photo of Pebble Count Sample.
**Kars One and Two (KZ1 and KZ2)**

These study locations reflect a survey of archaeological materials areas along a two and a half kilometre stretch of Rantyga Creek. First the general boundaries encompassing the larger survey location were re-established. Conditions along Rantyga Creek mirror those of Pine Creek, so a similar approach was followed. A survey was completed to mark the location of scalded areas within the re-established boundaries. A sample of these scalded areas was then selected in order to gain a representative spatial sample. Cores within selected areas were then identified, analyzed, photographed and returned to their original location. This effort resulted in 59 quartz and 25 silcrete cores from the KZ1 and KZ2 locations.
Figure 8.9: Kars One and Two (KZ) Survey Locations. (A) Map of Study Area Boundaries; (B) Typical View of Scalded Area Away from Creek; (C) Typical View Adjacent to Rantyga Creek.
Quartz is available in the immediate vicinity of the CN and KZ sampling areas in the form of gibber pavements and in dry creek lines. Rantyga creek channel is currently choked with sediment. Pine creek also contains large amounts of sediment that obscures much of the underlying cobble and gravel bed, but there are a number of exposures along the creek bed and banks where these materials can be examined. Two separate samples of quartz cobbles were taken at cobble bars (Figure 8.8 (C)) along sections of the creek line adjacent to the CN assemblages.

**Silcrete Quarry One (SQ1)**

The approximate boundary of the area sampled by Shiner (2004) was established with GPS. Because of the large area and high densities of worked and unworked stone, sampling in this area was completed by establishing sampling units over the long linear area represented by this locality. Because of the very limited time available for study at SQ1, cobble sampling simply reflected a grab sample of one or two cobbles from each unit. This resulted in a total of 24 silcrete cobbles that were analysed and photographed. Because of the low sampling density, Minimum Analytical Nodule Analysis at SQ1 was completed by examining all the cores within a five meter radius of the centre of each unit. Two separate raw material surveys were completed over large areas on either end of the SQ1 survey boundaries.
Figure 8.10: Silcrete Quarry One (SQ) Survey Locations. (A) Map of Study Area Boundaries; (B) View of Study Area; (C) Photo of Pebble Count Sample; (D) View of Study Area.
8.4 Summary

This chapter outlined the field work that was completed to further address the preliminary results of the cortex methodology. It outlined protocols used to reassess the average nodule size reduced at each of these assemblages as well as to determine raw material size ranges. In total 683 cores were reanalysed within the three study areas. Additionally, 19 raw material samples were taken. The data gathered in this effort will be interpreted in the next chapter.
Chapter Nine
Results of the Test of Cortex Patterning
9.1 Introduction

The preceding chapter outlined the data gathered at the Fowlers Gap, Pine Point Langwell and Paroo-Darling study areas. The additional core analysis and raw material surveys completed were designed to provide a more refined measure of Average Nodule Size as well as an alternative means with which to address the preliminary assessment that cortex was significantly underrepresented in the NSW study assemblages.

This chapter presents the analysis of the data acquired through this additional study. The new estimates of Average Nodule Size obtained with the regression models are contrasted with the distribution of natural cobble size variability determined with the raw material survey. Cortex Ratios are recalculated using refined Average Nodule estimates as well as an interpretation of the relative abundance of cobbles in the vicinity of each assemblage that are large enough to have cortical surface area and volume in equal proportion to that observed amongst the lithic artefacts at that assemblage.

9.2 Results of Field Methodologies

9.2.1 Estimated Average Nodule Weight

Table 9.1 shows the estimates of Average Nodule Size developed with the regression variables for each of the study assemblages for which additional core measurements were completed. Estimates made on the basis of cortex proportion are found in the column labelled “Cortex” while the estimates developed with multiple linear
regression analysis of the remaining core variables are labelled “MLR.” The models from which these estimates were based are reproduced below:

Cortex:

Less than 85% Non-cortical: Percentage of Nodule Mass Lost During Reduction = (Square Root Non-cortical Proportion x .978)^2; Greater than 85% Non-Cortical: Percentage of Nodule Mass Lost During Reduction = (Square Root Non-Cortical Proportion x .914)^2

MLR Silcrete:

Percentage of Nodule Mass Lost During Reduction = (Square Root of Scar Count Divided by Core Area x 1.271) + (Square Root of Exploitation Surface Interactions x .111) + (Log Natural transformation of exploitation surfaces divided by core area x -.010)

MLR Quartz:

Percentage of Nodule Mass Lost During Reduction = (Square Root of Scar Count Divided by Core Area x 1.814) + (Log Natural transformation of exploitation surfaces divided by core area x .019)
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<th>Material</th>
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<th>S.D. (grams)</th>
<th>MLR (grams)</th>
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Table 9.1: Estimated Average Cobble Weight from Sampled Assemblages. Estimate determined from cortex proportion labelled “Cortex.” Estimate determined with additional core variables labelled “MLR.”
As noted, the value of having two separate estimates of Average Nodule Size is that it helps to provide an increased level of certainty since close agreement between the two estimates would provide further assurance that Average Nodule Size is estimated accurately, while disagreement would lead to caution about the interpretative value of the results. What is apparent from these results is that there is close agreement between the two estimates for each of study assemblages suggesting that the estimates are a close approximation of the true average. Values do differ, but it takes considerable deviation to affect Cortex Ratios. For this reason, it is likely that the two separate estimates of nodule size will produce very similar Cortex Ratios. The accuracy by which average nodule size is approximated by these new estimates will now be checked against the raw material survey data.

9.2.2 Raw Material Size Variation

The raw cobble data obtained during application of the Wolman methodology provide a good perspective onto the range of stone raw material size values that can be obtained in the vicinity of each of the sampled study assemblages. These results, however, do not reflect the true proportion of cobble sizes from within each survey location (Leopold 1970; Dunkerly 1996). Instead, the raw data obtained with the Wolman method are biased in such a way as to over-represent the frequencies of larger stones. This is simply an effect of the increased size of larger stones creating a larger target and therefore having a greater probability of being selected at each sampling interval. As a result, cobble proportions reflect the “areal proportion” of the surface of a sampling location occupied by cobbles of a given size (Green 2003: 979; Leopold 1970), but must be transformed in order to accurately estimate the numerical
frequency of cobbles of different sizes within a sampling area. Leopold proposed a transformation to correct this bias based on weighting the size of cobbles by a “factor inversely proportionate to the square of the diameter of the b axis.” (1970:135).

In this study only cobble weight was obtained for the cobbles in each sampling area, however, average diameter (a near equivalent to the b axis) can be easily estimated from weight using linear regression. As previously noted, the relationship between weight and dimensional volume (length x width x thickness) of stone is highly correlated (Douglass et al. 2008). Average diameter is similarly correlated, but needs to be cubed in order for the relationship to be linear. Regression of the cube of average diameter of a cobble is highly correlated ($r^2: .992$; standard error: 46.05; p < .000; beta coefficient 1.062). The cube root of the value predicted with this equation gives a very useful estimate with which to gauge the sampling probability of each cobble in the Wolman data.

Leopold’s correction of sampling bias was calculated for individual cobbles rather than the size classes commonly used in pebble counts (see Dunkerley 1996 for a similar application). This weighting was $1/ (d^2)$ where d is the average cobble diameter, meaning the resulting weighted frequency values are proportionate, but individual values are all less than one (Leopold 1970; Dunkerley 1996:575). All values are multiplied by a factor to bring the weighted frequency value for the largest cobble recorded amongst all raw material surveys up to one. The recorded frequencies of all cobbles under 3500 grams were increased upwards in proportion to their sampling probability (and rounded to the nearest whole number). The result is a much
expanded data set for each sampling area that reflects the relative proportion of individual stone size frequencies rather than exposed area.

The resultant proportions for each study location are displayed for quartz and silcrete cobbles in graphical form in Figures 9.1 and 9.2. Pebble count proportions are generally presented as percent finer than for most applications. Here, however, the major point of interest is to know the proportion of stones equal to or larger than the cobble size that would reflect surface area and volume in proportion to that measured in the lithic assemblages. Because the interest is in larger cobbles, the data are presented as percent larger than.
Figure 9.1: Cumulative Quartz Cobble Percent Larger than Frequency Distributions. (Shaded area indicates range between first and third quartile of estimated cobble size)
Figure 9.2: Cumulative Silcrete Cobble Frequency Distributions. (Shaded area indicates range between first and third quartile of estimated cobble size)
As noted in Chapter Seven, the quantification of the natural cobble size distribution found surrounding each study area provides a useful point of comparison with which to further investigate the accuracy of estimates of Average Nodule Size determined with the regression models. If the estimates fall within the natural size range – thus demonstrating that the value used to calculate Cortex Ratios resembles a size that could be obtained from the materials used to produce an assemblage – it provides further assurance that Average Nodule Size is accurately measured.

In Figures 9.2 and 9.3 the range between the first and third quartiles of nodule values predicted with the additional core measurements is shaded in gray. These values fall well within the natural size range of cobbles from each area. Cobbles larger and smaller than those that fall within the quartiles range were selected, but the use of quartiles does give a good indication of the position of the estimated nodule values with respect to the range of cobble sizes that could be obtained locally. That core estimates fit so neatly within the natural size range provides a further indication of the accuracy by which Average Nodule Size was estimated for each of the sampled assemblages. These ranges provide further insights into the process of cobble selection for use in the production of stone artefacts. In general, the pattern in the estimated cobble values suggests a tendency to collect cobbles from the upper ranges of the natural distribution.

9.2.3 A Consideration of Cobble Selection

There is a general similarity in the quartz cobble sizes selected between all of the study areas, however, there is some variation in the range of cobble sizes selected. At
CN for instance, cobbles were selected over approximately 40% of the size
distribution (over 30 grams), while at FC selection was limited to approximately 20%
of the natural range of cobbles sizes. A similarity in cobbles size ranges between
locations but a disparity in the range of sizes selected reflects cobbles suitability and
selectivity at each of the study locations.

Silcrete on the other hand shows greater inter assemblage variation, much of this
reflecting the variable conditions under which the material naturally occurs. At ND
cobbles were selected from the size ranges available in the area, while at RH and SQ
cobbles were selected from a much finer range. CW shows the unusual tendency for
cores to be selected from the lower end of the cobbles size range. A likely cause of the
variation is the total range of cobbles sizes, the relative abundance of stone relative to
the surrounding landscape and the nature of past occupations at these locations.

ND has a smaller range of cobbles sizes and a prominent water feature (Murder Pool)
permitting more extended periods of occupation. It is the only WNSWAP study
location at Fowlers Gap with a source of silcrete in its immediate vicinity. These
circumstances encouraged a generalized approach to cobbles selection and the use of a
large variety of cobbles sizes. RH and SQ are located on boulder mantels associated
with outcroppings. They have more small cobbles than ND or CW as well as a
broader range of cobbles sizes as is indicated by the long tail in their frequency
distributions. Larger cobbles were rare but their presence made them worth seeking
out because of the greater versatility in flake products that could be made. While the
concept of a quarry is a difficult to operationalise in raw material rich western NSW
(Holdaway et al. 2008c), the location of these study areas away from water features
likely means that over the long term, prehistoric use of these locations was more fleeting than at either ND or CW. Limited amounts of time spent within the vicinity of a super abundant source of high quality stone resulted in more discerning raw material selection. At RH this tendency was further exacerbated by the presence of smaller cobbles of silcrete within the surrounding landscape. In essence small packages of silcrete were common but the larger ones selected at RH were not.

Finally, CW demonstrates a pattern that is opposite to that at RH and SQ. Currently, Pine Creek has a deep channel with a relatively large sediment load. When holding water, areas of exposed cobble bed surrounding these pools are limited and sediment obscures much of the dry area that surrounds these deeper pools. The density of artefacts, hearth chronology, and preliminary Cortex Ratio indicates that this location had more sustained occupations relative to the surrounding landscape (Holdaway et al. 2006). Stone availability was limited but extended occupations would have resulted in a greater willingness to use a larger range of cobble sizes. Repeated selection from a limited number of cobble exposures would gradually increase the proportion of smaller cobbles that were selected. Over the long-term, the spatial distribution of these locations of cobble bed exposure would change, but a tendency for longer occupations would ensure that the cycle towards smaller cobble selection would be repeated. In the aggregate, the distribution of predicted cobble sizes from a time-averaged assemblage when compared to contemporary and therefore recently resorted cobble exposures would show a tendency towards the selection of smaller cobbles from the natural size distribution. Within creek beds, there is an inverse correlation between raw material quality and cobble size (i.e. silcrete with fewer inclusions tends to be disproportionally represented by smaller cobbles). A preference
for finer grained stone would therefore further increase the proportion of smaller cobbles that were selected.

9.3 Summary

Results of the analysis completed with the data obtained through further study at Fowlers Gap, Pine Point Langwell and Paroo-Darling indicate that (1) estimates of cobbles size from cores are in close agreement between the two independent estimates of nodule size and (2) the size range of these predicted values generally falls well within the range of natural cobble sizes determined through the use of the Wolman Pebble Count. The combination of a general agreement between the two estimates and the fact that these values reflect cobbles that could easily be obtained from sources of local stone suggests that the variable Average Nodule Size is estimated accurately, thus providing a refined measure with which to assess the validity of the preliminary findings with cortex.

9.4 Recalculated Cortex Ratios

Table 9.2 shows the ratios obtained between observed and expected cortical surface area (i.e. the Cortex Ratio) for all the reanalysed western NSW study locations. These results include estimates recalculated with the refined measures of Average Nodule Size (Cortex and MLR) along with those produced in the preliminary study (Assemblage Mass Divided by Core Frequency).
<table>
<thead>
<tr>
<th>Assemblage</th>
<th>Material</th>
<th>Ratio (Cortex)</th>
<th>Ratio (MLR)</th>
<th>Ratio (Org.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN1</td>
<td>Quartz</td>
<td>0.72</td>
<td>0.73</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>Silcrete</td>
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<td>0.19</td>
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</tr>
<tr>
<td>CN3</td>
<td>Quartz</td>
<td>0.70</td>
<td>0.70</td>
<td>0.69</td>
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<td>0.16</td>
<td>0.17</td>
</tr>
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<td>0.56</td>
</tr>
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<td>0.67</td>
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<td>Quartz</td>
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<td>0.56</td>
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</tr>
<tr>
<td></td>
<td>Silcrete</td>
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<td>0.14</td>
<td>0.13</td>
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<td>KZ2</td>
<td>Quartz</td>
<td>0.69</td>
<td>0.67</td>
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<td></td>
<td>Silcrete</td>
<td>0.23</td>
<td>0.23</td>
<td>0.21</td>
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</tr>
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<td></td>
<td>Silcrete</td>
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<td>0.33</td>
<td>0.26</td>
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<tr>
<td>ND</td>
<td>Quartz</td>
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<td>0.94</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>Silcrete</td>
<td>0.40</td>
<td>0.39</td>
<td>0.37</td>
</tr>
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<td>RH</td>
<td>Silcrete</td>
<td>0.60</td>
<td>0.59</td>
<td>0.51</td>
</tr>
<tr>
<td>SC</td>
<td>Quartz</td>
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<td>0.79</td>
<td>0.67</td>
</tr>
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<td></td>
<td>Silcrete</td>
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<td>0.39</td>
<td>0.41</td>
</tr>
<tr>
<td>SQ</td>
<td>Silcrete</td>
<td>0.58</td>
<td>0.58</td>
<td>0.57</td>
</tr>
</tbody>
</table>

Table 9.2: Cortex Ratios for Reanalysed Study Assemblages. Ratios calculated with an estimate of Average Nodule Size determined with Cortex are labelled (Cortex). Ratios calculated with an estimate of Average Nodule Size determined through Multiple Linear Regression are labelled (MLR). Cortex Ratios presented in Chapter Six are labelled (Org).
With one exception, there is close agreement not only between the two measures determined through further core analysis, but also between these estimates and those that were presented in the preliminary study. This agreement strongly supports the validity of the initial observation that cortex is underrepresented amongst the WNSWAP assemblage data.

The one exception to this pattern deserves further consideration. Initial results presented in Chapter Six indicated a Cortex Ratio of .68 for ND quartz suggesting that quartz artefacts were removed from this location. Refined measures (Cortex .98; MLR .94), instead indicate that very little quartz was removed. Upon re-examining cores at this location, it was found that there were a significant number of small pieces of quartz gravel from which small flake scars has been removed. The inclusion of these cores in the initial measurement of cortex proportions therefore created a lower estimate of Average Nodule Size and the low Cortex Ratio reported in Chapter Six. While technically cores, these artefacts did not produce flakes big enough to surpass the two cm minimum size threshold required for analysis by WNSWAP and as such did not contribute to the pattern of missing cortex examined in this study. Their inclusion in the initial measure therefore created a false impression of missing cortex. This finding does, however, draw the question: What were these “cores” used for, as the source of diminutive flakes or as core tools? While the answer to this question is beyond the scope of this study, it does further highlight the definitional ambiguities that exist when classifying stone artefacts.

When only those cores large enough to have been the source of flakes greater than or equal to two centimetres are considered at ND, the recalculated Cortex Ratios are
quite high. This finding is of little surprise considering ND is the only assemblage analysed in the Fowlers Gap study area that is positioned next to a source of silcrete. Looking at the Cortex Ratios for ND silcrete (Cortex .40; MLR .39; ORG.37) it is clear that cortex is underrepresented from ND, but that raw material quality was significantly affecting decisions about artefact selection in that it was the higher quality stone that was selected for transport.

The finding that the recalculated Cortex Ratios have replicated original findings – thus suggesting the same overriding pattern of underrepresented cortex at each of the study assemblages using three independent measures – provides further evidence that cortex bearing artefacts are indeed underrepresented at the WNSWAP study assemblages. Furthermore that the refined results are generally in such close agreement with initial results, further supports the interpretation of missing cortex offered for those assemblages for which additional core analysis has not been completed. Finally, because the three independent measures of cortex proportions demonstrate such close similarity, inter-assemblage variation can be inferred to reflect the relative magnitude by which the process of artefact removal has influenced those artefacts that remain for study. Low ratios indicate places where greater frequencies of artefacts have been removed, while ratios that are relatively high indicate areas where removal was not so pervasive. Likely causes of this variation include the relative abundance of stone (i.e. flake production at locations of considerable material abundance may have been more profligate, thus enabling a greater wealth of choice for the selection of transported forms), as well as variation in the average occupation duration at each of these assemblages. Longer stays mean that greater quantities of the stone produced at a location are knapped, used and discarded at their place of
production. Stone is still likely to be removed, but the effect of this removal on Cortex Ratios will be lessened by the abundance of stone that was produced, used and discarded locally. Shorter occupations on the other hand will provide fewer opportunities for local abandonment, meaning the relative effects of transport will have a greater influence on Cortex Ratios.

9.5 Alternate Examination of Cortex Proportions

As noted earlier, it was desirable to investigate the pattern of underrepresented cortical surface area without the use of an estimate of Average Nodule Size. As described in Chapter Seven, this perspective can be gained by reordering the basic operation of the cortex methodology to determine the size of a cobble with cortical surface area and volume in proportion to that observed amongst the artefacts at each study assemblage and then comparing this value to the frequency distribution of cobbles from the stone source from which these artefacts were produced. Using the cobble size distributions determined with the Wolman pebble count data, I then calculated the relative frequency of cobbles that would have cortex and volume matching that measured in each assemblage.

In the graphical representation of the Wolman data presented in Figures 9.3 and 9.4, the bold line demarcates the mass represented by a cobble that would have cortex and volume in proportion to that measured amongst the artefacts within each of the WNSWAP assemblages. The frequencies of cobbles equal to or larger than this value for each assemblage (as well as their relative percentage) are presented in Table 9.3. These values always fall towards the high end of the natural size distribution. In fact, for the silcrete raw material surveys there was not a single cobble recorded that was
large enough to account for the cortex and volume observed amongst the artefacts in any of the WNSWAP assemblages.

Quartz displays a different pattern. Four of the five assemblages do have recorded cobbles equal to or larger than the size theoretically represented by the cortex and volume of the artefacts in the assemblage. This is a direct consequence of the higher Cortex Ratios of this material, and therefore the lower nodule size that would have cortex and volume in proportion to that measured in each assemblage.
Table 9.3: Position of a Cobble Large Enough to Have Cortex and Volume in Proportion to that Measured Amongst Assemblage Artefacts within the Natural Size Distribution of Cobbles Found in the Vicinity of the Study Area. Cobbles equal to or larger than the required size were found in very low proportions amongst some of the quartz sources, and were not observed amongst the silcrete sources. This suggests that the likelihood that cobbles of this size represent the average cobble size from which each assemblage was produced is extremely unlikely.

<table>
<thead>
<tr>
<th>Assemblage</th>
<th>Material</th>
<th>Cobbles &gt; Assemblage Cortex Proportions</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW</td>
<td>Silcrete</td>
<td>0/717</td>
<td>0.00</td>
</tr>
<tr>
<td>CN/KZ</td>
<td>Quartz</td>
<td>0/3902</td>
<td>0.00</td>
</tr>
<tr>
<td>FC</td>
<td>Quartz</td>
<td>2/1460</td>
<td>0.00</td>
</tr>
<tr>
<td>MD</td>
<td>Quartz</td>
<td>3/1349</td>
<td>0.00</td>
</tr>
<tr>
<td>ND</td>
<td>Silcrete</td>
<td>0/948</td>
<td>0.00</td>
</tr>
<tr>
<td>ND</td>
<td>Quartz</td>
<td>41/1339</td>
<td>0.03</td>
</tr>
<tr>
<td>RH</td>
<td>Silcrete</td>
<td>0/1654</td>
<td>0.00</td>
</tr>
<tr>
<td>SC</td>
<td>Quartz</td>
<td>139/4580</td>
<td>0.03</td>
</tr>
<tr>
<td>SQ</td>
<td>Silcrete</td>
<td>0/2099</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Figure 9.3: Cumulative Quartz Cobble Percent Larger than Frequency Distributions. (Black line indicates size of required nodule size (i.e. cortex and volume in proportion to assemblage measures). Shaded area indicates range between first and third quartile of estimated cobble size)
Figure 9.4: Cumulative Silcrete Cobble Percent Larger than Frequency Distributions. (Black line indicates size of required nodule size (i.e. cortex and volume in proportion to assemblage measures), Shaded area indicates range between first and third quartile of estimated cobble size)
The proportion of cobbles that fit into the required size range, however, is nonetheless exceedingly low, meaning the likelihood that cobbles of this size account for the bulk of the cobbles reduced to produce the assemblage is very unlikely. This observation is further supported by the fact that estimates of cobble size using the experimentally developed regression equations encompass size ranges well below this value, but well within range of cobbles that naturally occur at each of these locations.

In the case of ND, however, these arguments are less convincing. While cobbles of a suitable size occur only rarely in the area, this value does fall within the third quartile of the cores measured in the assemblage. While it is still doubtful that the average cobble size reduced at ND was as large as that required by the cortex and volume measured amongst artefacts in the assemblages, these results, just like those of the recalculated Cortex Ratios, indicate that the quantity of quartz removed from this assemblage was quite small.

Furthermore, while the bold line within the cobble size distributions presented in Figures 9.3 and 9.4 reflect the relative abundance of cobbles large enough to have cortex and volume in proportion to the artefacts within an assemblage, it must be remembered that this value represents what would have to have been the average cobble size reduced to produce each assemblage. The size of those cores with only one or two flake scars (termed test cores) along with those cores that retain a large percentage of their original cortical exterior indicates that cobbles much smaller than this value were clearly being worked at these assemblages. As such, cobbles even larger than this average would have at times been selected for reduction. From the cobble size data obtained, it is clear that cobbles much larger than this average value
are exceedingly rare if at all present in any of these study locations, thus further decreasing the likelihood that the assemblages reflect local artefact abandonment and therefore a lack of artefact transport away from these locations.

It is at this point that the results of the Minimum Analytical Nodule Analysis conducted at each of these study locations should be further considered. As described in Chapter Eight, comparison was made between the different cores that were sampled at each location to determine if multiple cores originated from the same cobble. For the majority of cores, distinctions could be made on the basis of gross raw material colour alone. Additional determinations for cores that possessed similar colours (particularly quartz) were made based on the texture and nature of inclusions, cortex colour and lustre, and finally position of residual cortex (i.e. only surfaces free of residual cortex have the potential to conjoin). Results indicate that while there was some evidence for the occurrence of multiple cores per nodule (Figure 9.5), the very small number of cases (n= 3) where this was demonstrated strongly suggests that cores within the western NSW assemblages follow the one-core-per-nodule pattern in the vast majority of cases.
Figure 9.5: Example of Multiple Cores per Nodule. Of the few cases where Minimum Analytical Nodule Analysis resulted in the identification of more than one core being created from a single cobble, the majority of these occurrences related the splitting of a core due a flaw in the original cobble, and the two separate cores were found in close proximity to one another. Examination of these cases indicated that flakes were seldom knapped on the surface created from the split, thus suggesting that the core was discarded soon after fracture had occurred.
It is this observation (i.e. the pattern of one-core-per-nodule predominates within the WNSWAP assemblages) that makes the frequency of cores measured in each of the archaeological assemblages of importance. The total mass of stone measured in an assemblage can be used to determine the total number of cobbles of a size large enough to have cortex and volume in equal proportion to that measured amongst the artefacts in the assemblage that should be found in an assemblage if all artefacts were discarded near to their place of production. That is, if it is assumed that cortical surface area is not underrepresented in an assemblage, then the mass of that assemblage can be used to determine the number of nodules (with cortical surface area and volume in proportion to the artefacts in the assemblages) that were reduced. This value can then be compared to the frequency of cores that are found in that assemblage. Recall that the core frequencies presented here, as well as in the preliminary cortex results presented in Chapter Six, exclude flake and bipolar cores. When core frequency is compared to the hypothetical number of cobbles that would be represented in the assemblage, core frequencies are much higher than the hypothetical number of cobbles required to account for the whole assemblage. This means that multiple cores would have to have been produced from each cobble of stone that was worked at each of the assemblages studied (Table 9.4). This scenario is in marked contrast to that identified through Minimum Analytical Nodule Analysis.
<table>
<thead>
<tr>
<th>Assemblage</th>
<th>Material</th>
<th>Theoretical Nodule Mass: (Cort./Vol.) Equal to Assemblage Values</th>
<th>Theoretical Nodule Frequency: (Cort./Vol.) Equal to Assemblage Values</th>
<th>Archaeological Core Frequency</th>
<th>Core: Nodule</th>
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</thead>
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<tr>
<td>CN1</td>
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<td>636</td>
<td>142</td>
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<td>794</td>
<td>78</td>
<td>398</td>
<td>5.1</td>
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Table 9.4: Comparison Between the Frequency of Cobbles that should be Represented in an Assemblage if it is Assumed that Assemblages had no Artefact Transport to the Number of Cores Measured in the Assemblage (Excluding Flake and Bipolar Cores). The Ratio of cores to the implied number of nodules is presented in the column “Core:Nodule.” These values are in marked contrast to the pattern indicated through Minimum Analytical Nodule Analysis at each of these assemblages.
9.6 Summary and Conclusion

The analysis completed with the data gained through additional field study at Fowlers Gap, Pinepoint Langwell and Paroo-Darling, provide a more in depth perspective on the initial study of cortex patterning amongst the WNSWAP assemblages.

New estimates of Average Nodule Size determined with the additional core measurements and the regression models developed in Chapter Seven provided a more refined measure of the average size of the nodules of stone that were reduced to produce the artefacts contained in the WNSWAP study assemblages. These two independent estimates were in close approximation to one another in each of the twelve study assemblages targeted for further study. Comparison of these results to the natural size distribution of stone cobbles found in the vicinity of each of these study assemblages, as determined with the Wolman pebble count, indicated that these values resembled cobbles sizes that could easily have been selected from the local stone sources from which the assemblages were produced. Combined, these results strongly suggest that the variable “Average Nodule Size” has been accurately estimated.

Cortex Ratios calculated with the new measures provided very similar Cortex Ratios to one another and to the initial results presented in Chapter Six. That three independent measures of the same value provided such similar results indicates considerable support for the initial observation that cortex bearing artefacts are underrepresented from these assemblages. Comparison of the relative proportion of cobbles found at stone sources in the immediate vicinity of each study assemblages provided an alternative perspective onto this observation.
The extreme rarity of stone cobbles large enough to have cortex and volume in proportion to that observed in the study assemblages strongly suggests that the observed pattern of underrepresented cortex found for all of the study assemblages could not have resulted from an error in the estimate of Average Nodule Size. Cobbles that would create cortex proportions as measured in the WNSWAP assemblages without artefact removal are not found in large enough frequency to have reasonably been the average size of cobbles chosen for reduction in these contexts. This observation was further bolstered by the fact that Minimum Analytical Nodule Analysis supported the initial assumption of one-core-per-nodule in the vast majority of cases, thus contradicting the relationship of multiple cores per nodule that would necessarily exist if very large cobbles were being reduced.

In Review:

Further testing has demonstrated that the cortex methodology consistently provides an accurate measure of archaeological cortex proportions.

The additional measures developed help to provide a further degree of refinement with which Cortex Ratios are calculated and interpreted, and application of these multiple independent measures indicated that the variable Average Nodule Size had been gauged correctly within the WNSWAP study assemblages.

Cortex Ratios calculated with refined estimates of Average Nodule Size replicated those of the initial study. An alternative perspective onto assemblage cortex proportions indicates that cobbles large enough to have cortex and volume in proportion to that
measured in the assemblages are extremely rare and that the production of multiple cores for each nodule (needed to balance core frequency to the theoretical frequency of cobbles with cortex and volume equal to that observed amongst the artefacts within each assemblage) did not eventuate.

In sum, by questioning the validity of the initial observations of cortex patterning, through the use of multiple independent lines of evidence, the same conclusion is reached that cortex bearing artefacts are indeed underrepresented from the assemblage targeted for further study. That refined measures consistently replicate the initial results is of significance for those assemblages at which additional study was not completed. Finding that variation in Cortex Ratios between the two refined measures mirrors that of the original methodology strongly suggests that the original Cortex Ratios are indeed correct and that cortex is consistently underrepresented for a sample reflecting over 123,000 artefacts distributed across a large portion of western NSW Australia. Finding abundant evidence for the widespread selection and transport of artefacts away from their place of production for use elsewhere, at every single locality at which this methodology has been applied across a vast study region, indicates that the operation of this process was a major component of the organization of lithic technology in the Australian arid zone. An interpretation of this pattern as it relates to the behavioural strategies utilized by Aboriginal populations to adapt to the demanding conditions of the Australian desert will be presented in the next chapter.
Chapter Ten

Implications and Conclusion
10.1 Introduction

The previous three chapters outlined the results of additional studies. The utility of the method for calculating the Cortex Ratio was confirmed and results of refined analyses replicate the initial observation of underrepresented cortex in the WNSWAP assemblages. Viewed from a variety of different angles, the quantification of cortical surface area consistently indicates that assemblages comprising over 123,000 artefacts distributed across a large region indicate the selective removal of overly cortical, and therefore large, flakes from areas of artefact production. That some artefacts were transported is not surprising since this is to be expected even with the most sedentary populations. What is remarkable is the magnitude of the discrepancy between observed and expected cortex values and the fact that the pattern was replicated in every assemblage studied. This result suggests that large artefacts selected for transport played a major role in Aboriginal technological organization.

This chapter addresses the behavioural implications of artefact transport. First, the relevance of this process for the archaeological understanding of lithic technological organization in the arid zone is considered. Discussion will then investigate how the pattern identified in this study can help to draw a greater understanding of the strategies of land use that were a necessary part of the Aboriginal adaptation to the demanding conditions of living in an sparse and unpredictable environment.
10.2 Western New South Wales Technological Organization

The structure of hunter-gatherer mobility and settlement is a consequence of the spatial and
temporal structure of critical resources within the environment (e.g. Binford 2001, 1980; Dyson-
the strategies utilized to equip individuals as they exploited these resources. As described in
Chapter Two, although much of the study region is comprised of ancient surfaces covering
upland features, it is in the geomorphologically more active and dramatically younger surfaces
within alluvial valley systems that the majority of lithic scatters and associated pit hearths are
found. Short-term spikes in the availability of water and resource abundance within these valley
systems were triggered by unpredictable and localized rainfall. Long-term human occupation of
this landscape led to a patchy archaeological record concentrated around ephemeral water
features, separated by diffuse artefact scatters and isolated artefacts in the desert that separates
them.

Through time, the unpredictability of water availability meant that place use was not highly
redundant. When the availability of water permitted occupation within these valley systems, the
sparse and unpredictable character of resource distributions meant that the actual act of foraging
was not spatially targeted. Because people ranged out far and wide in their efforts to obtain food,
they could not know precisely where stone suitable for the production of artefacts would be
found when needed. The response was a lithic technological strategy based on generalized tool-
kits (Kuhn, 1992, 1995), or personal gear (Binford 1977, 1979) carried at all times as a “hedge”
against unforeseen needs.
Kuhn (1994) discussed provisioning strategies and the design of mobile tool kits emphasizing how the efficiency and versatility in the form of transported artefacts helped to strike a balance between limited food resources and technological needs. The most efficient approach was to base tool kits on the transport of flakes and flake tools rather than cores since these provided a greater proportion of cutting edge relative to the weight of stone and ultimately required the transport of less waste material. These observations have relevance to the pattern of flake transport indicated by cortex from western NSW.

The Cortex Ratio measures the relationship between surface area and volume and is therefore sensitive to more than just the proportion of an artefact’s dorsal surface that is covered by cortex. The artefacts that most affect this ratio not only have a high proportion of cortex and large surface area, but are also thin and therefore have a low volume. The high edge to mass ratio that Kuhn identifies as important to the selection of mobile tool kits is precisely that which is most likely to create the deficits in cortical surface area observed in the WNSWAP study assemblages. The relationship between cortex proportion and flake size has further significance for a strategy emphasizing efficiency in the forms selected for transport.

Kuhn’s theoretical arguments about efficiency incorporated estimates of retouch potential into their measurement, but can easily be extrapolated to the measurement of edge perimeter relative to mass with a similar result. Larger flakes have lots of useful cutting edge which gives them a longer cutting surface and increased efficiency and effectiveness for cutting (Dibble 1995). Their increased size also affords greater leverage and therefore mechanical efficiency (Kuhn 1996, Morrow 1996). A demonstration of these qualities of larger flakes was provided by Prasciunas

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(2007) who found that smaller flakes are less effective for cutting tasks due to the awkwardness and fatigue associated with holding these smaller forms and the decreased amounts of cutting edge they provide. Her experimental study identified a clear correlation between cutting efficiency (measured by the total amount of cut denim), and flake size measured either by weight or area.

A strategy emphasizing a high edge to mass ratio and larger artefact size (with some limits, Kuhn 1994) makes sense under conditions of high mobility. Size and length of edge must be balanced against thinness to give efficiency in transport while still ensuring effectiveness in use. It is the selection of flakes that best represent this balance that created the deficit in cortex measured amongst the WNSWAP study assemblages.

Australian ethnographic accounts report how flakes were carried in small skin or string bags (e.g. Allchin 1957; Gould et al. 1971; Roth 1904), fibre sheathes (e.g. Binford and O’Connell 1984) or an individual’s headdress or hair (Mountford 1941:316; Tindale 1965:147). They also provide evidence of a process akin to the gearing up strategies Kuhn outlined when discussing the provisioning of mobile tool kits (e.g. Binford and O’Connell 1984; Gould et al. 1971; Hiscock 2004:74; Tindale 1965:140-41). Here, a succession of flakes were produced from a core, piled up, and the desirable pieces selected from the pile for transport. Production continued until the core either was exhausted (or failed) or a sufficiently large pile had accumulated, thereby amassing an abundance of flakes from which to make choices. These ethnographic accounts provide empirical support to the proposition that an emphasis on efficiency should result in the
preferential transportation of flakes rather than cores under conditions of mobility and that effort should be made to ensure that the forms selected are up to the task.

Archaeologically, the magnitude by which cortex is underrepresented in the NSW assemblages indicates that the transport of flakes as personal gear was fairly widespread. Aboriginal populations relied on frequent bouts of “gearing up” with large thin and therefore disproportionately cortical blanks at locations with material abundance during periods of downtime. These artefacts were then carried as people moved throughout the greater landscape. Despite differences in the temporal scale of observations, this interpretation of the archaeological record supports ethnographic observations about high mobility levels with short-term residential occupations.

10.2.1 Is this Curation?

That the process is replicated in such a broad sample of assemblages in western NSW gives credence to the assertion that at least some examples of Aboriginal lithic technology placed considerable emphasis on artefact selection and transport. Can this finding be considered as evidence of curation? To answer this question the archaeological definition of curation needs to be reconsidered.

In his original formulation of the concept, Binford (1973:242) commented, “once produced or purchased [an artefact] is carefully curated and transported to and from locations in direct relationship to the anticipated performance of different activities.” Here, the process of curation
involved the investment of effort into the preservation of artefacts so that they could be of use in future activities. Artefacts subject to curation were often retained beyond the context of their production, therefore their presence in archaeological assemblages was not in direct proportion to their frequency of use but instead reflected the rate at which they were discarded.

Based on this definition of curation, the identified pattern of missing cortex provides a measure of the effects of artefact curation on assemblage formation. Rather than a casual technology, assemblages comprised of unretouched flakes and informal cores suggest a sophisticated use of stone artefacts to ensure the availability of edge as people moved throughout the unpredictable environment of the Australian arid zone. The fact remains, however, that though there is abundant evidence for extensive transport and therefore artefact curation, there is little evidence of the kinds of artefact maintenance upon which most studies of the curation process are based. This has implications for how the process of curation is diagnosed archaeologically in many research contexts.

Artefact use and maintenance involves a nonlinear loss of mass. Though rates of edge attrition may vary greatly depending upon the material worked as well as the artefact edge angle, many tasks can be accomplished without the need for edge modification. Various experiments in animal butchering (e.g. Braun et al. 2008; Walker 1978) as well as the working of harder materials like wood (e.g. Collins 2008; Shott and Sillitoe 2005) suggest that unretouched flakes are highly effective tools, particularly in cutting soft material like animal tissue (Kuhn 1991). Walker (1978), for instance, conducted a series of butchering experiments on a variety of animal species (e.g. deer and sea lion) and concluded that the margins of unmodified flakes were
generally more effective than the retouched edges of bifacial tools for activities like slicing muscle tissue. While some have argued that unretouched flake tools can be used only briefly in their unmodified state (e.g. Brose 1975), others have found that considerable amounts of work are possible before artefacts are discarded or require retouch (e.g. Braun et al. 2008; Collins 2008).

These findings have implications for the relationship between retouch and curation. It is only after retouch is initiated, for instance, that any appreciable reduction in artefact utility as defined by Shott (1989, 1996) can be measured. As retouch intensity proceeds, edge angle and thickness along the retouched edge increase, meaning that each successive stage of edge maintenance removes a larger portion of artefact mass (Hiscock and Clarkson 2005). If use occurs without the need for any edge maintenance, the ‘utility’ of an artefact remains intact over this time only to be removed relatively quickly once retouch commences. A delay in edge attrition, and therefore the need for retouch, means that many artefacts selected for future use and therefore potentially affected by the process of curation may go un-noted by measures that use retouch intensity.

As discussed in Chapter Five, much of the patterning in artefact retouch intensity may relate to differences in raw material access and therefore the need to economize the use of stone. If stone is difficult to acquire, retouch intensity is often found to increase presumably reflecting an effort to extend the serviceability of existing forms. Where stone is abundant, fewer flakes receive the secondary edge modification that would result in their classification as retouched tools. Raw material availability in western NSW affects economizing behaviour and the relationship between curation and retouch, just as it does in other parts of the world (e.g. Andrefsky 1994a,
1994b; Odell 1996; Nash 1996). Raw material is abundant as outcroppings, in watercourses and as surface stony desert cobbles. As a consequence, marginal retouch is rare and often non-invasive (Holdaway et al. 2004).

Because curation reflects the act of organizing and preserving tools in order for them to be available when needed, it is contextually and contingently dependent. The same process of curation, with the same objective, and for cutting tools producing the same general trajectory of use, may produce a variety of different outcomes depending on local circumstances. Curation may therefore exist in situations of both raw material depletion and abundance. Where material is scarce, more artefacts will require edge maintenance and some artefacts will therefore be reworked extensively. Where material is more abundant, artefacts may still be curated, but the process may be less intensively geared towards the maintenance of individual forms. The process of equipping individuals with useable edge in these cases may be best served by placing greater care in artefact selection, carrying them to meet future needs and then discarding them before they become too worn, only to be replaced with fresh selected artefacts as an alternative to edge retouching. As Kuhn (1991:101) observes, “…[P]eople who make and maintain tools long in advance of anticipated use might be expected to replace worn elements relatively frequently to ensure against the possibility of failure. Thus, the people who depend most on curated tools may be expected to abandon them at a relatively early stage of reduction.”

Given the right conditions, it is no wonder that people would replace worn edges. In the material rich environment of western NSW, people moved flakes; transported forms were preserved for future use, and on average these flakes were retained in service longer than the non-transported
variety. When dulled, however, they were replaced. Such a strategy was facilitated by selecting thin high-edge-to-mass flakes that provide abundant readymade edge in a portable package, transporting several of these, and then replenishing stocks during periods of down time around the frequently encountered raw material sources. This was curation, and for it to have resulted in a deficit of cortex of such a magnitude, in assemblages comprising over 123,000 artefacts distributed across much of western NSW, indicates that the use of this process was a major component of the technological strategies Aboriginal populations utilized to cope with the unpredictable and difficult conditions of the Australian arid zone. This was no casual process.

10.3 Cortex Patterning and Landscape Organization

Finding that Aboriginal populations applied sophisticated means to the organization of their technologies where previous studies have suggested otherwise is an important observation. However, as described in Chapter Five, of greater interest is the potential offered by the study of technological organization to establish links between archaeological remains and the greater organizational systems populations utilized to adapt to the unique physical and social circumstances faced within different environmental contexts. The archaeological record of western NSW is spatially concentrated; the organization of the behavioural systems responsible for its formation, however, operated at a greater spatial scale.

To this point, I have outlined how the curation of large thin flakes relates to a technological strategy that facilitated effective and efficient technological solutions for use under conditions of high mobility. Beyond relating how the pattern in cortex is an artefact of people’s efforts to
select efficient forms for transport, the spatial relationships that exist in cortex patterning can provide further insights into the structure of these past systems of land use. It is this aspect of the patterning of cortex that is of greatest value for its ability to inform on the organization of the past.

10.3.1 Spatial Patterning in Cortex Proportions

Cortex Ratios with values less than one indicate something of the extent of movement in that repeatedly there is a dearth of cortex in assemblages adjacent to semi-permanent water. Like refitting and material sourcing studies, the analysis of cortex provides insights into the mapping relationships between artefact production and discard. Unlike these techniques, however, the cortex pattern is not a direct measure of the distance of individual artefact transport, but instead is a measure of the magnitude by which the process of transport has produced an impact on the composition of the entire record that remains for study.

Because the pattern is a measure of all material produced through reduction, it provides the potential for a more comprehensive perspective on the nature of land use. Observations of long distance transport of individual tools indicate that some forms were transported great distances, and thus can provide some indication of the distances people occasionally travelled. The limited number of artefacts upon which these studies are often based, however, complicates the ability to provide an indication of the general patterns of mobility and land use practiced by a population. That cortex patterning exists at the assemblage level means that the patterning displayed in cortex proportions is a cumulative pattern reflecting the average spatial relationship between an
artefact’s point of production and its point of discard. The pattern of missing cortex is in effect a spatial phenomenon. Artefacts were created, used, transported and then discarded; at any given location cortex may be over or underrepresented, but by extending the spatial extent of observation outward the balance in cortex proportions will eventually be restored. This is an artefact not only of the distance artefacts were removed from their place of production, but also the scale at which these removed artefacts were eventually inherited elsewhere.

This phenomenon can be illustrated with a simple diagram (Figure 10.1) showing the movement of overly cortical artefacts from a source of stone. Within the vicinity of a stone source, the Cortex Ratio for artefacts not selected for transport is below one. This is the pattern demonstrated in the WNSWAP study assemblages. If the spatial scale of analysis is extended outward, however, Cortex Ratios will increase as the location of discard for transported artefacts is eventually encompassed. In effect, extending the scale of analysis outward from areas depleted of cortex bearing artefacts will eventually “get around” any disequilibrium in cortex proportions. Because the stone at any given location does not exist in isolation, the effect of artefact transport from other locations will also affect this pattern. As artefacts from other locations are inherited, expanding the scale at which a Cortex Ratio is calculated will eventually increase the ratio beyond a value of one.
Figure 10.1: Diagram Illustrating the Spatial Relationship between Artefact Transport and Cortex Patterning. Outward arrows indicate the straight line distance and direction of artefact transport radiating from a point of artefact production. Inward arrows indicate the transport of artefacts from other locations. The Cortex Ratios calculated for an area near to a source of stone from which large thin and therefore disproportionately cortical artefacts were removed will be below one. As the scale of analysis is extended outward, curated artefacts removed from that location, as well as others moved from elsewhere, will be encompassed and the Cortex Ratio will increase. Eventually the scale of observation will be sufficiently large to mediate against the imbalance that exists in cortex proportions. The scale at which this happens at any given point on the landscape therefore provides important insights into the nature of artefact curation, and by extension land use, that occurred throughout the history of record formation for the spatial unit that is being observed.
Exploring variation in cortex patterning at different scales provides the basis for making inferences about ranging behaviour and territorial organization. It is possible to ask: How does this aggregate pattern of artefact transport relate to the long-term use of place, and how can the scales at which imbalances in cortex proportions persist be utilized to draw inferences about the nature of land use in the past?

Before discussion of Aboriginal land use can proceed, however, it is important to note that an imbalance in cortex is not a direct analogue for human movement in the past. Understanding the scale at which Cortex Ratios return to one does not equate with the total distance of movement. The pattern instead is a consequence of a number of behavioural characteristics, each of which is of interest to understanding land use in prehistory:

*Frequency of Movement:* Greater sedentism will result in more artefacts being discarded near to their place of production, while greater mobility will mean that a larger proportion of the artefacts produced will have the potential to be transported away. Movement relates to both individual and group mobility, both at the scale of residential moves and individual movements through space. Cortex Ratios therefore are directly affected by the relative rate of movement around the landscape.

*Linearity of Movement:* Differences in the nature of movement within the landscape will have different effects on cortex patterning even if the rate of movement and artefact transport is held constant. Movement possessing greater numbers of uncorrelated turns decreases the velocity with which individuals move across the landscape. As a result, though artefacts may
be transported for a considerable time over a considerable distance, their ultimate linear
distance from their place of production may be quite short. The same amount of transport, for
the same time, and same total distance, but in a more linear pattern of movement, will result
in a much greater linear distance separating an artefact’s point of discard from its point of
manufacture.

Ecologists exploring animal movement characterise differences in the linearity of movement
paths using the concept of tortuosity or sinuosity of movement (Dicke and Burroughs 1988;
Sugihara and May 1990). Theoretically, levels of tortuosity range from a straight line path of
movement to a path so tortuous that it completely covers a plane without crossing itself
(Roshier et al. 2008). Higher tortuosity of movement results in a much more thorough use of
the landscape, while higher linearity enables quick and rapid movement through a landscape.
This can be illustrated with a simple hypothetical diagram representing two different
movement paths. In Figure 10.2, movement path A reflects a highly tortuous and therefore
more circuitous use of habitat, while movement path B reflects a more linear and therefore
less thorough pattern of land use. Differences in the directionality of movement affect the
velocity with which individuals traverse the landscape. Extending these patterns to a
discussion of stone artefact transport indicates that differences in the average movement path
will have a major effect on the kinds of patterning that will emerge in cortex proportions.
Greater linearity equates with a greater potential for Cortex Ratios to deviate from one over
larger spatial distances, while more thorough land use will buffer against the scale at which
an imbalance in cortex proportions will persist.
Use life: Finally, while the cortex pattern reflects movement, it is not a direct analogue for the scale of individual human movements. It is instead a reflection of the intersection of the previous two factors (rate and tortuosity of movement) and artefact use-life. Artefacts kept for a longer period of service will necessarily have the opportunity to be transported over greater distances. How much time investment was given to individual stone tools therefore has a major influence on the spatial patterning in cortex proportions that result.

The term use life relates to the total time of possession between production and discard for an individual artefact. This definition can relate to the single sequence of production use and discard by one individual or multiple episodes of use as would be expected for caching, recycling and scavenging. The reason for drawing this distinction in the use of the term use life is that in archaeological measures of time and artefact use life it is not uncommon for researchers (e.g. Shott and Sillitoe 2005) to equate use life with time in use. While such a definition has its own merits for addressing tool using behaviour, for mobility, time of use matters little, but time over which the functionality of an individual artefact was made available through curation matters a great deal.
Figure 10.2: Diagram Illustrating Differences in the Tortuosity of Movement Paths. From the perspective of artefact curation, increased tortuosity and therefore thoroughness of landscape coverage will limit the total distance that an artefact can travel. The long-term implication for cortex patterning under different modes of land use is clear. The curation of large thin flakes under a system of land use similar to that in movement path A will create variation in Cortex Ratios, but these deviations are not apt to persist over great distances. The same technological strategy but under a system of land use such as that illustrated in movement path B will produce imbalances in cortex proportions that persist over vast territories.
Variation in Cortex Ratios relates to the interrelationship between artefact use life, the degree of transport and the long term structure of human movement within a system of land use. Transported forms were removed from their place of production and ultimately discarded elsewhere; the scale at which variation in Cortex Ratios persists therefore reflects the operation of this process viewed at the temporal resolution related in the archaeological record.

Researchers working in what has been termed ‘Movement Ecology’ (Holden 2006; Mueller and Fagan 2008) have used variation in animal movement paths to understand variation in the strategies utilized to access food and water resources, acquire mates, and maintain territories. Central to these ideas is the assumption that landscape structure, most notably resource density, heterogeneity and patch connectivity, is a major determinant in individual movements and population-level distributions (e.g. Kareiva and Odell 1987; Turchin 1998; Zollner and Lima 1999).

Habitats that provide a high energy density promote a more thorough coverage and lower velocity. Movements within these habitats tend to follow an “encamped walking pattern” where individuals form territories and home ranges (Mueller and Fagan 2008). In contrast, habitats of low energy density with patchy resource distributions promote less tortuous movement paths and higher velocity across the landscape. Individuals and groups within these habitats tend to engage in “explorative walks” and are less likely to maintain circumscribed territories (Kareiva and Odell 1987). The overall nature of movement, however, is likely to vary at different spatial scales as a reflection of habitat structure. Between-patch movements across less desirable
portions of the landscape are apt to have low tortuosity, while within-patch movements are apt to be more tortuous as more intensive searching for resources occurs.

10.4 Implications of Cortex for Understanding Aboriginal Land Use

Turning to the WNSWAP study assemblages, the pattern of underrepresented cortex indicates that the selective transport of large thin flakes was pervasive within the arid zone. Within this study environment there are concentrations of artefacts and hearths separated by a very low density scatter that persists across the greater deserts that exist between these places. In effect, the patterning in the Australian record reflects concentrations at nodes that were frequently targeted for human use.

The pattern of underrepresented cortex indicates that the general tendency of artefact movement was for a large portion of the artefacts that were produced to be selected and transported beyond the boundaries of archaeological survey. The implication of this pattern is that visits to these places were generally short enough that many of the artefacts produced and selected for use were not discarded in their place of production, but were instead transported for use elsewhere. At the scale of observations afforded by the different surface assemblages analysed by WNSWAP, the velocity of movement across the landscape and away from these targeted locations was great enough to sap fairly large areas of artefact cortex. What remains unclear from this observation, however, is what the general structure of the systems of land use responsible for this pattern looked like.
In Chapter Six I offered two scenarios through which the pattern of missing cortex could emerge. One related to the transport of artefacts as individuals moved within a foraging zone while the other related to a process of gearing up with artefacts between larger scale residential movements. In the occupation histories of each of the WNSWAP study areas it is fairly certain that both scenarios took place. What is of relevance is the average length of time in which people maintained themselves within the areas surrounding these assemblages and the relative velocity at which peopled moved across the greater landscape.

If the pattern of missing cortex reflects a tendency for people to exploit an extended foraging zone radiating off from these areas of water and raw material availability, then while people may have been quite mobile it is possible that the overall territory over which they ranged in the short-term was not that large. This pattern is emblematic of the rate of territorial velocity displayed in the classic foraging patterns recorded ethnographically where people exploited an extended foraging zone for a short period of time (e.g. Yellen 1972). The succession of “search loops” created as foraging parties set off from a base camp, gathered resources within a foraging zone and then returned creates a daisy-chain pattern centred on the base camp (Figure 10.3).

Such a pattern of land use would see the repeated back and forth movement of people within the foraging zones. A “leapfrog pattern” (Binford 1982:) of overlapping zones then forms over-time as people repeatedly moved camp to adjacent areas once resources were depleted (Figure 10.4). The long-term effects of such a strategy of land use would deplete cortex from nodes on the landscape, just as observed in the WNSWAP assemblages, but it is unlikely that cortex would be extensively over or under-represented at larger spatial scales because the decreased linear distance of artefact transport and the averaging effect of short non-routed individual and
residential movements across the landscape would tend to cancel each other out. Such a pattern of land use reflects high mobility as people moved to acquire resources but a fairly circumscribed territorial range at any given point in time.
Figure 10.3: Daisy-chain Pattern of Land Use (After Binford 1980: Figure 2). Here foraging parties set out from a base camp, complete “search loops” within a foraging zone and then return to camp. The succession of foraging loops off of a base camp resembles the petals of a daisy. This was the pattern of land use observed by Yellen amongst a mobile group of Dobe !Kung (1972).

Figure 10.4: Leap Frog Pattern of Residential Camp Movement (After Binford 1982 Figure Two). The long-term operation of this pattern of mobility and land use based on a technological strategy of flake curation will deplete cortical surface area from nodes on the landscape, but it is unlikely that cortex would be extensively over or under-represented at larger spatial scales because of the decreased linear distance of artefact transport and the averaging effect of short non-routed individual and residential movements across the landscape. Here for instance, most artefacts produced at Site A will be discarded within the foraging and logistical radii that surround it. Those not discarded, will be transported to the next camp. The long-term operation of this system will constrain the spatial scale at which an imbalance in cortex may persist, especially as zones are superimposed on one another through time.
Alternatively, if the pattern of missing cortex reflects a pattern of landscape mobility that saw limited occupation within localized foraging zones and frequent, long distance, moves over a large territory, then the less tortuous, higher velocity nature of landscape usage would increase the total linear distance covered by an artefact over the course of its use life. The preferential selection of large blanks for transport away from their location of production would have the effect of creating a deficit of cortex from locations that afforded opportunities for artefact production, selection and removal, again replicating the pattern observed archaeologically. But because larger distances were covered during such moves, imbalances in cortex proportions would persist at larger spatial scales. Such a pattern of land use is more indicative of the kinds of logistic movements associated with hunter-gatherers who rely on storage and the maintenance of long-term occupation sites and specialized facilities (Binford 1980), but this needn’t be the case under all conditions. Instead, frequent long distance movements could be practiced by fairly nomadic groups and individuals moving within a vast and operationally undifferentiated territory.

These two alternatives demonstrate the fact that land use practices with very different levels of tortuosity and landscape velocity could create the same pattern of missing cortex that exists within the WNSWAP study assemblages. Different patterns of land use have different implications for the nature of the long-term adaptation required for the maintenance of Aboriginal populations within the arid zone. Determining which set of strategies more adequately portrays the circumstances of the prehistoric occupation of western NSW requires investigation of assemblage patterning at a scale beyond that afforded with the existing WNSWAP study assemblages.
10.5 Landscape Archaeology at Rutherfords Creek, NSW

Over the past four years WNSWAP has completed additional study along Rutherfords Creek within Paroo-Darling National Park. This study represents an expansion of the WNSWAP methodology to a much larger spatial scale, that of an entire catchment basin, and offers the potential to utilize cortex to further investigate the question of prehistoric Aboriginal land use.

The advantage of catchments as landscape units is that their floodplains present a broad circumscribed spatial unit across which archaeological remains of similar age can be studied. There is potential for variation in temporal grain across these surfaces, but the underlying structure of the alluvial system makes control of this variability more manageable. Additionally, as a landscape unit, catchments have real ecological and therefore behavioural significance in that the areas within their boundaries present zones of relative water and resource abundance within the sparse desert landscape that surrounds them. From the perspective of mobile populations utilizing this environment, these areas present fairly discrete packages of desirable habitat.
Figure 10.5: Views of Rutherfords Creek, April 2006. (Top) View of Rutherfords Creek floodplain and surrounding uplands. (Bottom) Overview of Rutherfords and Howells Creek catchments from Round Hill.
The Rutherford Creek catchment itself (Figure 10.5) presents a broad open floodplain—measuring approximately 10 km in length by one to two kilometres in width. Rutherford Creek is one of a number of alluvial valleys that radiate around and drain into Peery Lake. Pools dispersed within individual creek channels can hold water for weeks following localized rainfall and in the aggregate these valleys afford the collection of water runoff from rainfall over a broad area surrounding the greater lake system. The lake itself is part of the Paroo-Darling overflow and fills following periods of heavy rains. Once full, it holds water for months to over a year. In addition to these water features, there are mound springs distributed around the Peery Lake shore that provide small but persistent water availability. The relative abundance of water and by extension food resources within the greater lake system made it a desirable location for human usage relative to other contexts within the larger study region. It does, however, experience all the localized and unpredictable environmental variability that typifies the greater study region.

An abundance of medium to high quality silcrete is found in the Rutherford Creek channel and in patches of gibber positioned along the valley floor. Scatters of flakes and cores produced from this material, along with hearth features, are found within networks of eroded scalds distributed across the whole catchment. These areas present individual windows into the archaeological record that exists across the whole floodplain.

The locations of individual scalds across the valley were mapped and their areas measured. Combined areas of artefact exposure amounted to 1,675,982 m$^2$ or 13% of the total valley floor area of 13,186,552 m$^2$. A random sample of scalds, amounting to approximately 5% of the area of archaeological exposure, was selected for further analysis across the valley floor. Artefacts
totalling 24,354 were analysed, with an overall density of .29 artefacts per square meter. Extrapolating these numbers to the greater catchment suggests that upwards of 487,000 artefacts are exposed and an additional 3.3 million artefacts and hearths may remain buried by sediment (Fanning et al. 2009b).

OSL and radiocarbon dating was used to investigate the formational histories of these deposits, providing an occupational history upon the floodplain surface. In total 1054 hearths were recorded; 256 were selected for excavation, of these about one-third had sufficient charcoal to produce conventional age estimates. Gaps exist in the chronology of individual hearth clusters, thus replicating the wider pattern of WNSWAP hearth chronologies noted elsewhere. At the scale of the entire catchment, however, the aggregate pattern shows no breaks in occupation at the resolution of radiocarbon (Fanning et al. 2009b). Instead the valley chronology demonstrates fluctuations in the rate of hearth construction through time. Some time periods have very few hearths, while other show relative increases in hearth construction. These fluctuations correlate with oscillations in the Mindanao sea core, showing that the rate of hearth construction and therefore the frequency of occupation across the floodplain was susceptible to global patterns of environmental deterioration (Holdaway et al. 2010).

The additional methodologies developed in this study were also completed at Rutherfords Creek as part of the WNSWAP recording protocol and through independent study completed in 2007 and 2008. Table 10.1 presents estimates of average cobble size determined through the use of the additional core measurements. The values produced show close agreement between the two independent estimates of average cobble size, thus suggesting that this value was measured
accurately. Five raw material surveys along the creek line show the natural raw material cobble size distribution found within the study area. The first and third quartile range of predicted cobble size indicates that these values fit well within the size range of silcrete raw material that can be found within the valley (Figure 10.6).

Table 10.1: Estimated Average Cobble Weight from Rutherfords Creek. Estimate determined from cortex proportion labelled “Cortex.” Estimate determined with additional core variables labelled “MLR.”

<table>
<thead>
<tr>
<th>Study Location</th>
<th>Material</th>
<th>Cores Measured</th>
<th>Cortex (grams)</th>
<th>S.D.</th>
<th>MLR (grams)</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC</td>
<td>Silcrete</td>
<td>864</td>
<td>257.98</td>
<td>303.7</td>
<td>203.98</td>
<td>227.48</td>
</tr>
</tbody>
</table>

Table 10.1: Estimated Average Cobble Weight from Rutherfords Creek. Estimate determined from cortex proportion labelled “Cortex.” Estimate determined with additional core variables labelled “MLR.”
Figure 10.6: Rutherford's Creek Cumulative Silcrete Cobble Percent Larger than Frequency Distributions. (Black line indicates size of required nodule size (i.e. cortex and volume in proportion to assemblage measures), Shaded area indicates range between first and third quartile of estimated cobble size)
Figure 10.7: Rutherford's Creek Cortex Ratios. Shading indicates variation in ratio values.
10.5.1 Rutherfords Creek Cortex Proportions

Measurement of cortex proportions indicates substantial variation in the effect of artefact curation on the assemblage contents that remain for study. Figure 10.7 presents a map of the range of Cortex Ratios calculated for the analysed scalds. Some scalds reflect substantial artefact removal, while others do not. In fact, a few low density scalds have ratios values that show an over abundance of cortex.

The spatial pattern created by these values defies simple interpretation. There is no apparent trend showing correlations between location within the valley floor and scald Cortex Ratios. Values, for instance, are not higher or lower with respect to distance from either the creek line or the lake shore. Instead, variation appears to be almost random. In effect, just as was observed at Pine Point Langwell (Chapter Four) (Shiner 2004, 2008), spatial variation in assemblage contents does not reflect modal tendencies in place use, but instead a highly variable pattern reflecting changes in the use of space over time. The implication is that within the Rutherfords Creek catchment, like the other WNSWAP study locations (Holdaway et al. 2008b), insufficient overprinting exists to produce a behavioural uniformity in lithic assemblage patterning. This is a broad and therefore abundant record of artefact variability, but as a record of accumulation over the long-term, shorter term variability still leaves a noticeable effect on the patterns that emerge.

Combined scald values for the whole catchment, using both estimates of average cobble size, produce Cortex Ratios of .56 (Cortex) and .52 (MLR). Using the alternative measure of cortex presented in Chapter Seven, catchment wide cortex proportions were used to calculate the
average size of the stone cobbles needed for these values to exist if assemblage contents reflected complete technological expedience. The theoretical cobble size that was produced through this measure, 1471 grams, falls well beyond the values determined through additional core measurement (Table 10.1) and is at the very later end of the size distribution of locally available stone cobbles determined with use of the Wolman method (1954). In fact, only five of the 5018 cases represented in the size corrected cobble frequency data were as large as this theoretical value. Finally, Minimum Analytical Nodule Analysis indicated that the production of multiple cores for each nodule (needed to balance core frequency to the theoretical frequency of cobbles with cortex and volume equal to that observed amongst the artefacts within each assemblage) did not eventuate. The implication is that, measured several different ways, cortex is truly underrepresented across the whole catchment, meaning that many of the artefacts produced at Rutherfords Creek were transported beyond its boundaries.

This is an interesting observation because it means that movement across the valley was of high enough velocity for a lot of the stone that was reduced there to leave. Cortex Ratios at this scale of analysis, however, are higher than the general pattern found amongst WNSWAP study assemblages indicating that while artefact transport was substantial, less material was removed beyond the study boundaries than is typically indicated at other locations. This effect is likely a reflection of the pattern of short-scale foraging within the broader catchment, meaning that the aggregate pattern of foraging within this resource patch was more thorough (i.e. more tortuous) than is displayed at the finer spatial scales measured in the other WNSWAP study assemblages. The pattern, however, does still indicate that of the artefacts produced within this area, a large enough quantity were transported beyond the catchment boundaries so that the cortex amongst
the nearly 3.8 million artefacts that remain for study is still under represented by greater than 40%.

This finding has important implications for understanding the general nature of land use as it unfolded over the approximately two thousand years of record formation in the Rutherfords Creek floodplain. Long-term movement was tortuous enough that some transported artefacts were discarded within the catchment, but a lot were not. Was this pattern the result of land use based on a classic foraging pattern, but at a scale that saw the extension of foraging and logistical radii beyond the boundaries of the catchment, or was it more representative of the alternate scenario of a land use strategy based on frequent long distance movements across a much larger territory?

Moving away from the catchment, there are two options for the extension of human mobility. Either movement out from the larger system represented by Peery Lake and its related alluvial valleys, or around that system, moving perpendicular from one creek channel into the floodplains and catchments of adjacent creeks. Spatially this pattern can be thought of as moving away from Peery Lake out into the uplands and sand plains that surround it or alternatively moving around the larger lake system in a circular pattern of land use.

Away from the lake system the dynamic geomorphological environment of the valley floor with surfaces of relatively young age changes into a less dynamic environment with surfaces of much greater antiquity. Artefact densities are concentrated upon the younger surfaces within alluvial valley systems and of markedly lower density upon the more ancient deserts that surround them,
even though these older desert surfaces reflect accumulation over a much longer period of time. Explorative surveys across the ancient surfaces surrounding Rutherfords Creek have failed to find appreciable artefact densities except along stone outcroppings such as that found at Round Hill. Instead, the record that exists upon these surfaces presents a diffuse scatter of small groupings of artefacts and individual isolates within a largely un-watered and denuded landscape. If this is where the artefacts whose removal is responsible for the catchment wide deficit of cortex are found, then the area at which a Cortex Ratio of one could be realized must be well beyond the scale of individual foraging zones. If movement was typically at this scale, then the densities indicated by this record implicate land use based not on a strategy of return trips from a sustained base camp, but a pattern marked by individual and group movements across a much greater territory.

The alternate explanation for the deficit in cortex within Rutherfords Creek, that based on the extension of foraging behaviour beyond Rutherfords Creek into the network of valley systems surrounding Peery Lake, presents other implications for land use. If each valley system had similar use histories, then a deficit of cortex should not emerge at the scale of an entire catchment basin. This is because movement of artefacts out of one catchment would see their deposition within another. The net effect of artefact transport at the level of whole catchments would be close to zero, meaning it is unlikely that any one valley system would present a Cortex Ratio well below or above one.

This is not the case at Rutherfords Creek, meaning that for the pattern to emerge through a circulating pattern of mobility, the use of different valleys within the larger lake system through
time must not have been uniform. Under this scenario, the observed pattern could reflect a tendency for the Rutherfords Creek catchment to be subject to greater artefact export, while adjacent valleys tended towards greater import. Extending the scale of analysis to include an adjacent catchment should then encompass the scale of mobility reflected by the movement of stone around the larger lake system.

To investigate this possibility, survey during the 2008 field season extended beyond Rutherfords Creek to the adjacent catchment of Howells Creek. The headwaters of the Rutherfords and Howells catchments are separated by uplands, but as these creeklines approach Peery Lake, their floodplains connect.

Time precluded a systematic sample of artefact exposure across the floodplain of Howells Creek. Instead, surveys of surface visibility were completed, and a selection of scalds distributed along the floodplain was selected for further analysis. Analysis was not as intensive as that completed for Rutherfords Creek, but the scalds selected for study provided a representative sample of assemblage patterning found within the Howells Creek catchment. The Cortex Ratio values for these scalds are presented in table 10.2.

<table>
<thead>
<tr>
<th>Scald</th>
<th>Observed CSA</th>
<th>Expected CSA(Cortex)</th>
<th>Expected CSA(MLR)</th>
<th>Cortex Ratio (Cortex)</th>
<th>Cortex Ratio(MLR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>46217</td>
<td>1035</td>
<td>1925</td>
<td>2081</td>
<td>0.54</td>
<td>0.50</td>
</tr>
<tr>
<td>46219</td>
<td>2389</td>
<td>5021</td>
<td>5430</td>
<td>0.48</td>
<td>0.44</td>
</tr>
<tr>
<td>46275</td>
<td>793</td>
<td>1341</td>
<td>1450</td>
<td>0.59</td>
<td>0.55</td>
</tr>
<tr>
<td>Combined</td>
<td>4217</td>
<td>8287</td>
<td>8961</td>
<td>0.51</td>
<td>0.47</td>
</tr>
</tbody>
</table>
These are all below one, and in the aggregate give a values of .51(Cortex) and .47(MLR). The implication is that cortex patterning within Howells Creek mirrors that found at Rutherfords Creek, meaning that cortex was removed from this valley as well. Similarly, results from Charlton Well (reported in Chapters Four and Eight) display a similar deficit in cortex. This assemblage is located on Pine Creek which runs west of Rutherfords creek and also drains into the larger system connected to Peery Lake (Figure 4.4). The area of this assemblage is smaller than that of Rutherfords and Howells Creeks, but the identified pattern suggests that a similar process of broad scale artefact removal is at work. The result is that the analysis of cortex proportions from assemblages within three adjacent catchments positioned along a broad area surrounding Rutherfords Creek consistently indicates that cortex is underrepresented. The implication of this finding provides important insights into the nature of long-term land use surrounding the greater Peery Lake environment.

This was not a pattern created by extended occupations where people would locate themselves along creeklines and then select artefacts for use while foraging around the greater environment of the Peery Lake system. Such a pattern would see artefacts selected for transport during foraging within this zone and deposition away from areas of increased artefact density, but the back and forth pattern of land use that would result would not allow the creation of a large imbalance in cortex proportion. Artefacts would be moved from one catchment and into another. Through the long-term repetition of the “Leap Frog” pattern of residential movement (Binford 1980) around the lake system, cortex would be underrepresented near to the material sources within the creeklines, but this imbalance would not persist across an entire catchment. The pattern displayed at Rutherfords and Howells Creeks does not reflect land use within a fairly
circumscribed territory surrounding Peery Lake. Movement through this system was of high enough velocity that people frequently abandoned the area thus moving into the extensive open landscape that exists in the areas that surround it. WNSWAP has not as of yet completed systematic surveys of these low density areas, but it is clear that the scale at which the identified imbalance persists was large.

The implication is that the general nature of land use within the environs of Peery Lake, and by extension the region of western NSW, involved rapid movement across the larger landscape. In all likelihood this pattern reflects a land use strategy of group and individual movements to take advantage of opportunities of water and resource availability, briefly employing a strategy of more thorough within-patch foraging and then abandonment as individuals and groups moved to yet another opportunity at some distance. As stated, Peery Lake and its surroundings presents a relatively water rich environment compared to the greater study region. Water pools within individual creek lines hold water for weeks and the lake itself can hold water for much greater periods of time. While water may have been available to sustain longer occupations, it did not occur often enough to have an appreciable effect on cortex patterning measured for the 5% sample of valley wide artefact exposure. A likely reason for this is that while water may have been available, the sparse resource base even within these higher density zones was not sufficiently abundant to support long sustained human occupation. People would quickly consume resources within the immediate environment to the point where diminishing returns prompted the abandonment of the area. The result was then relocation to another foraging zone. The localized nature of rainfall meant that the areas separating the next zone of habitation were
likely large, patch connectivity was extremely low, and populations would then have to depend on long distance movements at scales well beyond those accommodated by this study.

The results of these observations with cortex give an indication of the spatial extent over which lithic technological organization operated in arid Australia, a result that ties in well with the temporal structure of critical resources within this environment. A high level of mobility and an unpredictable climate and resource base helps explain a settlement pattern that shows little understandable pattern at the level of a single drainage system (Shiner 2004, 2008). The same general location might be repeatedly occupied but not necessarily to exploit the same resource suite (Holdaway et al. 2008a), and these targeted areas represented only part of the greater expanses where lithic technology might be needed. A strategy based on the transport of large thin flakes would thus ensure that technological needs were met as people completed long distance movements across a vast landscape.

10.6 Conclusion

This thesis addressed the relationship between an archaeological record dominated by unretouched flakes and informal cores and the demanding context of the Australian arid zone. Although it has been said that Australian assemblage variability reflects a casual approach to lithic technology (Chapter Two), the pattern of cortex indicates otherwise. Beyond addressing the question of whether or not the organization of Aboriginal lithic technology was simple, this research provides a framework through which researchers can realize the explanatory potential of these morphologically informal artefact assemblages. By moving beyond a discussion of the
artefacts themselves, to an understanding of their organization within the greater Aboriginal adaptation to the environment of western NSW, this research demonstrates a sophisticated strategy for ensuring the availability of technological solutions within a system of land use based on rapid mobility to utilize the sparse and unpredictable resources of a desert landscape. This pattern largely reflects the organization of technology geared not to the conditions that persist in the vicinity of locations of artefact density, but instead to the conditions that exist elsewhere. It is through use at the “in-between” places in the wider Australian landscape that the true value of these curated forms was realized.

Lithic technological organization and the utilization of the curation process is not constant but is instead contextually and contingently dependent. How people organized their technology was dependent on a variety of factors, including the availability of raw material, the relationship between time of artefact use and time of artefact production and the nature of land use and territorial organization. The organizational significance of stone artefacts therefore comes not through investigating their morphology, but through an understanding of their use as technological solutions within past behavioural systems. Significance is not to be found in the presence of formalized tool forms, the complexity of artefact manufacture or the intensity of their maintenance. Instead it is the complexity that assemblage contents display when analyzed with respect to the unique contextual challenges faced when living within a given environment. Different circumstances fostered different solutions, and the choices made at any given time were met with varying degrees of success. Of behavioural interest is how past populations organized themselves to meet unique physical and social conditions, and the long-term viability of these adaptations. In other words, it is variability in contextualized response in a given
environment and its implication for understanding higher level behavioural organization that forms a better research focus rather than any consideration of artefact complexity.

The sophisticated organization implicated through this study demonstrates the kinds of behavioural response required to adapt to the unpredictable and demanding conditions that existed within the western NSW study region throughout the mid to late Holocene. The long-term viability of a hunter-gatherer population within this demanding environment speaks to the merits of this adaptation. Though at face value the lithic technologies of western NSW may appear simple, their place within past behavioural organization was anything but.
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Yellen, John E.


Zollner, P. A. and Lima, S. L.

### Appendix One: WNSWAP Artefact Definitions

**Artifact types**

<table>
<thead>
<tr>
<th>Artifact Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angular fragment</td>
<td>Incomplete flake</td>
</tr>
<tr>
<td>Angular fragment tool</td>
<td>Incomplete flake with retouch</td>
</tr>
<tr>
<td>Bipolar core</td>
<td>Crushing on opposing ends with a negative flake scar</td>
</tr>
<tr>
<td>Block</td>
<td>Worked stone with no evidence of flake scars</td>
</tr>
<tr>
<td>Broken Flake</td>
<td>Neither a platform nor a termination, but at least one lateral margin</td>
</tr>
<tr>
<td>Broken split</td>
<td>Either a platform or a termination (but not both) with a snap at right angle to either the platform or termination</td>
</tr>
<tr>
<td>Broken tool</td>
<td>Neither a platform or a termination, but at least one lateral margin and retouch</td>
</tr>
<tr>
<td>Complete bipolar flake</td>
<td>Crushing on opposing ends</td>
</tr>
<tr>
<td>Complete Bipolar tool</td>
<td>Crushing on opposing ends and retouch</td>
</tr>
<tr>
<td>Complete flake</td>
<td>Platform and termination</td>
</tr>
<tr>
<td>Complete split</td>
<td>Platform and termination with a longitudinal snap from the platform to the termination</td>
</tr>
<tr>
<td>Complete split tool</td>
<td>Platform and termination with a longitudinal snap from the platform to the termination and retouch</td>
</tr>
<tr>
<td>Complete tool</td>
<td>Platform and termination and retouch</td>
</tr>
<tr>
<td>Core</td>
<td>Block with one or more negative flake scars or a flake with negative flakes scars on the ventral surface</td>
</tr>
<tr>
<td>Distal flake</td>
<td>A termination and no platform with a snap</td>
</tr>
<tr>
<td>Distal tool</td>
<td>A termination and no platform with a snap and retouch</td>
</tr>
<tr>
<td>Hammerstone</td>
<td>No flake scars and pecking on at least one surface</td>
</tr>
<tr>
<td>Medial flake</td>
<td>Both lateral margins, but no platform or termination</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Medial tool</td>
<td>Both lateral margins with retouch on either one or both but no platform or termination</td>
</tr>
<tr>
<td>Milling slab fragment</td>
<td>Flat ground surface</td>
</tr>
<tr>
<td>Muller</td>
<td>Grinding facets on at least one surface</td>
</tr>
<tr>
<td>Proximal flake</td>
<td>Platform and no termination with a snap</td>
</tr>
<tr>
<td>Proximal split</td>
<td>Platform and no termination with both a transverse and longitudinal snap</td>
</tr>
<tr>
<td>Proximal tool</td>
<td>Platform and no termination with a snap and retouch</td>
</tr>
</tbody>
</table>
Appendix Two: WNSWAP Artefact Attribute Definitions

**Raw Material**

*Amorphous silcrete*  
Non-clast matrix

*Clast silcrete*  
Fine to medium clast matrix

*Coarse silcrete*  
Coarse clast matrix

*Crystal quartz*  
Transparent

*Matrix dominated silcrete*  
Predominantly non-clast matrix

*Milky quartz*  
White and non-transparent

*Opaque quartz*  
Semi Transparent

**Distal End (Termination Type)**

*Abrupt*  
High angle termination

*Feather*  
Acute angle termination

*Hinge*  
Meets the surface at approx. right angle to the longitudinal axis

*N/a*  
Termination cannot be assessed

*Plunge*  
Terminate has a J shape in the longitudinal cross section

**Cortex Proportion**

*None*

*1-50%*

*50-99%*

*Complete*

**Cortex Type**

*Gibber*  
Rounded and smooth

*N/a*  
Cortex type cannot be assessed

*Non-gibber*  
Non-rounded outcrop surface
Flake Form

*Blade*  
Length greater than width with parallels lateral margins and parallel dorsal flake scars

*Block*  
Thickness is greater than width

*Contracting*  
Proximal portion is wider than the distal

*Expanding*  
Distal portion is wider than the platform

*N/a*  
Form cannot be assessed

Proximal End (Platform Type)

*Bi*  
Flaked platform with scars from two opposing directions

*Cortical*  
Cortex present on platform

*Crushed*  
Damaged, but the point of force application is visible

*N/a*  
Platform missing, cannot be assessed

*Uni*  
Flaked platform with scars from one direction

Exterior Platform Modification

*Cortex*  
Cortical surface

*Scar*  
Dorsal flake scar

*Trimming*  
Small negative flake scars with step termination

Tool Type

*Backed blade*  
Backed on at least on end, sometimes both, sometime on one lateral margin as well

*Burren*  
Flakes or flake segments with steep retouch on at least one lateral margin and a transversely convex ventral surface. Many have retouch scars that are step terminated

*Burin*  
One or more flakes scars running down the margin of the flake

*Denticulate*  
Retouch forming more than one adjacent cuspate notches
Eloura
A crescentric form like an orange segment that is symmetrical in the transverse axis but asymmetrical in the longitudinal axis

Notch
Retouch forming one or more single cuspate notches

Pirri
Points with retouch encroaching onto only one flake along the lateral margins

Scraper
Continuous macroscopic scalar retouch

Tula
Flakes that have pronounced bulb of percussion and a wide platform, retouch is initiated on the ventral surface and occurs from the distal end and the lateral margins so that all portions more distal than the bulb of percussion have been removed

Utilised
Edge nibbling that may be discontinuous

Core Type

Biddirectional
Platforms flake from opposing ends

Bifacial
Platforms flake from two directions

Bipolar
Crushing on opposing ends with a flake scar.

Flake Blank
Core produced on a flake

Microblade
Multiple parallel flake scars across core surface

Multiple
Platforms flaked from three or more directions

Nuclear Tool
Retouched Platform

Radial
Platforms flaked either unifacially or bifacially in a circular patterns towards the centre

Test
One or two flake scars on a cortical cobble

Unifacial
Platforms flake from a single direction

Retouch Description

Backed
Steep unifacial or bifacial retouch

Notch
Single cuspate notch
**Scraper**  Continuous macroscopic scalar retouch

**Step**  Continuous macroscopic scalar retouch with step fractures

**Utilised**  Edge nibbling

**Quadrants (clockwise)**

**One**  Platform

**Two**  Lateral Margin

**Three**  Distal end

**Four**  Lateral Margin

**Dimensions and Exterior Platform Angle**

**Maximum length**  Greatest dimension in an orientation

**Maximum width**  Greatest dimension at any point at right angles to the length

**Maximum thickness**  Greatest distance between the dorsal and ventral surfaces wherever this occurs

**Percussion length**  From the point of impact to the point where the force exited the core

**Percussion width**  Distance between lateral margins at right angles to, and half the distance along the length measurement

**Percussion thickness**  Distance between the dorsal and ventral surface at the point where the thickness and width measurements intersect

**Platform width**  Distance between the lateral margins measured across the point of impact

**Platform thickness**  Distance from the ventral surface adjacent to the point of impact to the closest point on the dorsal surface

**Core scar**  Length of the longest cores scar from the negative point of impact to the point where the forces left the core

**Exterior platform angle**  Angle between the platform and the dorsal surface measured at the point of impact